PHYSICO-CHEMICAL AND BIOLOGICAL PROPERTIES OF WATER ALONG MUTONGA RIVER IN EASTERN KENYA

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DECLARATION

This is my original work and has not been presented for the award of any degree in any university or for any other award.

Signature: ……………………………….… Date: ………….……………………….

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The work presented in this thesis was carried out under our supervision.

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DEDICATION

I dedicate this research work to my family. They sacrificed so much throughout the duration I was studying. To my dear husband Daniel, thank you for all your hold up. To my son Deric and daughter Leslie, thank you for the understanding and encouragement you accorded me. May God’s blessing follow you.

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ABBREVIATIONS AND ACRONYMS

AAS	Atomic Absorption Spectroscopy
APHA	American Public Health Association
BDL	Below Detection Limit
CNS	Central Nervous System
DO	Dissolved Oxygen
FC	Fecal Coliform
EC	Electrical Conductivity
GPS	Global Positioning Systems
KEBS	Kenya Bureau of Standards
NEMA	National Environment Management Authority of Kenya
PCBs	Polychlorinated biphenyls
PET	Polyethylene terephthalate
TC	Total Coliform
TDS	Total Dissolved solids
TSS	Total Suspended Solids
WHO	World Health Organization

ABSTRACT

Levels of chemical, biological and physical parameters provide information on quality of water. Human activities together with natural processes affect the level of water parameters. River Mutonga is a trans-boundary river traversing tea, irrigation and semi-arid regions as well as quarry sites. These activities may lead to introduction of pollutants that may change the levels of water parameters. Water from this river is used for household and irrigation activities and also by animals. This study’s aim was to investigate the levels of parameters in water and sediment samples collected along the river in the dry and wet seasons. The levels of pH, Electrical conductivity (EC) turbidity and temperature were measured using corresponding portable meters. Levels of Total dissolved solids (TDS) and Total suspended solids (TSS) were determined using standard procedures by APHA. Levels of metals were investigated using AAS spectrometry, while nitrates and phosphates were measured using UV-VIS procedures. The results were statistically analyzed using Kruskal-Wallis and ANOVA tests to determine significant differences in parameters by sites and seasons. In water, mean ranges of parameters in the two seasons were: pH: 5.67±0.00 - 7.74±0.16, Temperature: 13.50±0.10 - 26.60±0.10, EC: 0.13±0.06 - 93.50±0.10, Turbidity: 14.89±2.18 - 1000±0.67, TSS: 38.83±3.21 - 100.33±17.77, TDS: 29.33±33.33 - 444.00±287.52, Pb: 0.00 - 0.28±0.02. Cd ranged from 0.00 - 0.003±0.00, Fe: 0.27±0.02 - 7.65±0.13, Mn: 0.00 - 2.22±0.06, NO_3^-: 0.49±0.00 - 4.89±0.06, PO_4^{3-}: 0.24±0.00 - 3.83±0.00. In sediments ranges were Pb: 13.82±5.67 - 32.33±11.02, Cd 0.00 - 0.816±13.38 while Fe ranged from 9.12.58±32.08 - 46770.83±938.19. Mn ranged from 249.92 ±15.25 - 816.16025±13.38, NO_3^- :1.95±0.00 - 4.99±0.01 while PO_4^{3-} ranged from 0.22±0.00 - 0.816±13.38. Total and fecal coliform ranges were 41.53 - 467.33 cfu and 7.86 - 150.019 cfu respectively. There are significant differences in levels of physical parameters between seasons and among sites except TSS. The chemical parameters in water and sediments vary significantly among sites except lead in sediments and all vary between seasons apart from phosphates in water and nitrates in sediments. Biological parameters differ significantly between seasons and among sites. Levels of turbidity, TSS, lead, iron and coliform bacteria are above WHO permissible limits. The high levels suggest that the river water is polluted.

CHAPTER ONE: INTRODUCTION

1.1 Background information

Water is an essential factor playing a pivotal role in maintaining environmental balance. Good quality of water is directly connected to good human welfare (Kithaka *et al*., 2020). Everyone in the world, regardless of his or her status, deserves to access water of good quality and sufficient quantity (Tarakegn and Truye, 2018). Pollution of water is the change in its levels of physical, chemical and biological characteristics caused by pollutants (Bartram, 2015). It involves introduction of unwanted substances and disease-causing pathogens, leading to their accumulation in surface water resulting to lack of balance in ecosystems (Haseena *et al*., 2017). Water quality is very much affected by agricultural, industrial and overabundance of human activities. This causes an alteration in the amount of physical, chemical and diversity of microbial organisms in water in the river (Singh and Sao, 2015).

Demand for fresh water is increasing every day and quality water as a resource is already limited. Thus, water pollution confers more pressure to the strained water resources. Polluted water causes harm to human health, hinders aquatic activities and has lowered quality thus affecting its ability to support economic activities such as agricultural and industrial activities (Jimoh and Vogler, 2011). Good water quality should meet some certain set mandatory standards at local and global levels (WHO, 2011). The set standards are used as the major administrative tools by which the status of water quality is monitored and managed for various uses. In Kenya, the set standards are formulated by bodies like NEMA and KEBS (Ondoo *et al.*, 2019).

Industrial and agricultural activities cause water pollution and the polluted water can contain many metals like cadmium, arsenic and mercury. It can also contain man-made organic compounds such as PCBs and pesticides (Teck *et al*., 2017 and Sonja *et al*., 2010). Bio-solids, the principle biological water contaminant that introduce coliforms among other pathogenic bacteria in portable water may be part of effluent and waste water. Water which is polluted hosts disease vectors like vibrio which causes cholera and schistosomiasis transmitted by a parasitic worm (Bartram, 2007). Consumption of water containing *E. coli* leads to giardness, dysentery and gastroenteritis (Isikue and Chikezie, 2014). When human beings consume water rich in nitrates; it may lead to "blue baby" disease of the infants (methemoglebinemia). They also contaminate aquifers and can be responsible for human poisoning (Bonareri *et al*., 2017).

Release of contaminants coming from diverse point sources such as storm water, domestic, industrial wastes, runoff from agricultural activities has either short-term or long-term effects on water consumers (Singh & Sao 2015). However, the scope to which each factor adds to poor water status is unclear (Zhang *et al*., 2010). When more and more effluent and waste water get their way into the rivers and streams, their fundamental role of providing clean water for domestic, agricultural, industrial and other uses get compromised (Tamungang *et al*, 2016 and Olatunji *et al*, 2015).

Sediment destroys habitat for small animals which live at the bottom of rivers like fish. Sediments can create problems for humans too because they change how the water flows. River sediments act as sinks for heavy metals and nutrients like phosphates and nitrates. Heavy metals precipitation results to attachment onto the surface of sediments at elevated pH (Islam *et al*., 2014). River water quality has been devalued through discharges of wastewater which contain nutrients organic substances, household wastes, and wastes from agricultural sources (Dimitrovska *et al*., 2012). Eutrophication is brought about by too much nutrient loading in water. Eutrophication results in harmful algal blooms which threatens aquatic plants and animals. Additionally, emerging pollutants like cosmetic products and pharmaceuticals present in water affects water resources, resulting to unknown long-lived effects on ecosystems and human health (Ezbakhe, 2018).

1.2 Statement of the Problem

Rivers are major surface water sources of fresh water for use in domestic, agriculture and in industries in most parts of the world, (Masere *et al*., 2012 & Huq *et al*., 2013). With the rapidly growing human population, the need for more food and alternative income sources has multiplied. In addition, there is an increased demand for sufficient and clean water for use by the growing population for irrigation activities, domestic purposes and for livestock. Hence the need for water quality investigation in water sources. Mutonga River is a shared resource between Meru and Tharaka-Nithi Counties in Kenya. This river traverse tea, coffee and tobacco farms in addition to irrigation zones for horticulture. It also passes through zones where extensive quarrying is carried out as well as semi- arid regions. All these may result to discharge of pollutants into the river which may affect the levels of water parameters. Escherichia coli and animal fecal matter which contain nutrients and waste from dairy farming and animal husbandry may as well add to water contamination. Hence, there was need for this study.

The research investigated the levels physical properties (TDS, pH, TSS, turbidity, EC and temperature). Levels of heavy metals namely, lead, iron cadmium and manganese were also investigated. The study also investigated the levels of anions (nitrates and phosphates), and those of total coliform and fecal coliform in water. In sediments, levels of lead, cadmium, iron, manganese, nitrates and phosphates were investigated. The investigations were carried out in the dry and the wet season.

1.3 Justification

Despite the fact analysis of water quality has been carried out on most rivers in Kenya no information is documented on status of water along river Mutonga. With the fast-growing human population, there is an increasing demand for water of good quality which is already insufficient. Water parameters in Mutonga watercourse are likely to be altered by the discharge of pollutants resulting from various activities along the river. The water quality in this river needs to be checked and protected to make sure it is suitable for use by the growing population in the two counties, hence the need to examine its parameter levels.

1.4 Null Hypothesis

The levels of physical, chemical and biological parameters along Mutonga River are not above WHO recommended levels and do not differ significantly along the river during the dry and wet seasons.

1.5 Objectives

1.5.1 General Objective

To investigate the levels of chemical, physical, and biological parameters in water and sediment samples along Mutonga River during the dry and wet seasons.

1.5.2 Specific Objectives

i. To determine the levels of turbidity, pH, TDS, TSS, EC and temperature in water samples collected along Mutonga River during the dry and wet season.

ii. To determine the levels of Pb, Cd, Fe, Mn, nitrate ions and phosphate ions in sediment and water samples along Mutonga River during the dry and wet seasons.

iii. To determine the levels of total coliform (TC) and fecal coliform (FC) count in water samples along Mutonga River during the dry and wet season.

1.6 Significance of the study

The results of this research work will provide information to the county governments of Meru and Tharaka-Nithi about status of water from Mutonga River is fit for domestic purposes. They can act as useful informer to the environmental management bodies like NEMA on status of water quality in rivers and necessary actions to be taken. They can act as a source of background information to researchers in a similar study. The findings will also add to the body of knowledge on effects of anthropogenic and natural activities on quality of river water.

1.7 Scope and limitations

This study investigated the concentration of chemical, physical and biological parameters in water and sediments along Mutonga River. Samples of water and sediments were picked in seven selected locations representing zones of various activities carried out downstream. Levels of six physical parameters in water, four heavy metals, phosphates and nitrates in water and sediments, fecal and total coliform in the water were investigated. Sampling of water and sediments was done along the river only in dry and wet seasons. The limitation of this study is that the results in the study might have been affected by the climatic changes experienced in the recent past. This was overcome by taking samples in early October and late November for dry and wet seasons respectively.

CHAPTER TWO: LITERATURE REVIEW

2.1 Water Availability

Water is a precious and crucial resource in the world. It has been reported that about 1.4 x10^9 Km^3 of water is held on earth as seas, oceans, rivers, lakes, and ice (Ehailu *et al*, 2017). The percentage of fresh water found in lakes, ground water and rivers is 0.3 percent of the available water sources this is polluted, it presents an enormous negative effect to human, animal and plant lives (Ehailu *et al*., 2017). The available portable water is continuously facing increased pollution day by day due to increased human activities. In Asia, Latin America and Africa, there has been an increase in severe microbial pollution found in a third of the rivers. Out of ten, seven rivers are organically polluted and moderate salinity is found in a tenth of all the rivers.

Agricultural chemicals contribute greatly to nutrient pollution and are projected to continue increasing beyond the year 2020, with nutrient pollution being concentrated in the South and Central America and in countries of Sub- Saharan Africa (UNEP, 2017). Rivers are the commonest and paramount fresh water sources of for use. River water is facing serious pollution effects due to human activities. River and lake water is more open to increased pollution when compared to other water sources because of the direct contact with myriads of activities of humans (Gichuki & Gichumbi, 2013).

2.2 River water pollution

Contamination of fresh water sources with a wide range of pollutants is becoming a serious issue all over the world in the last few decades. This is due to aquatic ecosystems receiving heavy metals from occurring naturally processes and deposits together with human activities (Wogu and Okaka, 2011). The main sources of metals in rivers include municipal effluents, industrial sources in addition to non-point source run offs.

The entry of heavy metals into river ecosystems and other aquatic environment changes the diversity of aquatic species and ecosystem sustainability because of their accumulative behavior as well as their toxicity. Dissolving of high-density metals in water is a threat to the lives of people who use the water for consumption and other domestic purposes (Wogu & Okaka, 2011).

Pollution of water is an evolving phenomenon though it is greatly ignored (UNEP, 2017). Greenpeace as reported by Andrews (2018), published an article that out of 421 rivers in the Philippine, fifty were found to be dead biologically. Biological death means that the rivers lack oxygen to support life in water (Andrews, 2018). In Philippines, it was noted that hazardous wastes are the discharged by manufacturers into Laguna Lake and Pasig River. These wastes from industries contained heavy metals: cadmium, chromium, mercury and lead. Other pollutants found in water comprises decayed Pollution of water is one of the most severe environmental issues in China, particularly in large urban areas and human settlements.

Research on the quality of water in the Yangtze River reported a marked reduction in numbers of water vertebrae due to the declining amount of oxygen. This was attributed to factors such as acid deposition, improper land use, nutrients and the existence of dangerous matter (Sonja *et al*., 2010). In western Asia, Iraq, Euphrates River serves as of the main source of irrigation water. Plants wastes, animal manure, soil runoff, remains of dead animals, unexpected oil spills, chemical spills and deposit of wastes which is illegal (Andrews, 2018). Studies done on River Euphrates and Tigris showed high levels of physico-chemical parameters in the water which included TDS, pH, DO and microbial pollutants which contributed to the lower quality of water. These contaminants make the water unsuitable for irrigation, industrial and domestic purposes

(Haithem *et al*., 2018). The level of metals found in water differs between seasons. An example is in Netherlands where water in rivers was found to have higher levels of copper and lead in wet season than dry season. This was attributed to surface run off that carries materials into the water and the prolonged existence of copper complexes in sediments which dissolve with increase in the volume of water (Sultan *et al*., 2012).

Sediments in rivers are known to act as surface for deposition of heavy metals. At high pH, compounds of the heavy metals undergo precipitation and get attached onto the surfaces of the sediments. The metal contamination in sediments sampled from rivers may change with seasons due to changes in volume of water which affects concentration of substances (Islam *et al*., 2014). Sediments are important components of the aquatic habitats. They are reservoirs for contaminants, playing a notable role in the maintenance of the trophic balance for any water body. They act as sources as and sinks for nutrients and other compounds. Sediments are therefore potential secondary sources of contaminants in the aquatic ecosystems. For these reasons, analysis of river sediments is useful in the study of metal and nutrient pollution in river water (Ondoo *et al* 2020). Metals are stored in to river banks and in sediments found in channels which become future sources of pollution in the rivers. The extent to which they act as sources of pollution depends on nearness or distance of contaminated sediments to the active channel, the nature of landscape and earth’s surface along the river (Islam *et al*., 2014).

Buriganga River water in Dhaka (Bangladesh) is used for domestic and agricultural activities. Research was carried out on the quality of water in this river and it revealed that there were high levels of physical parameters which included electrical conductivity, turbidity, pH, TDS, DO, BOD and COD. Concentration of anions (phosphates and nitrates) was noted to be beyond acceptable limits (Shaikh *et al*., 2016). An investigation on the status of water in Osun urban centers in Nigeria revealed that parameters such as temperature, EC, TDS pH, were high. This was associated with domestic effluents and surface runoff carrying dissolved solids. Nitrates and phosphates concentrations were high as a result of wastes from animals and human beings and use of inorganic chemicals fertilizers. An increase in temperature causes dissociation of water molecules to more H^+ ions and dissolution of acidic compounds into the water. High temperatures influence many chemical processes like dissolution of minerals which may increase water TDS and conductivity (Marina *et al*., 2013).

Total coliform count was found to be high. This was attributed to leaking of fecal matter into the underground water (Ogunbode *et al*., 2016). The wastes get into river water and may alter the levels of water parameters. The heavy metals coming from agricultural inputs, atmosphere, industries, domestic wastes and quarrying activities collect on soil surfaces and the upper layer of sediments in water. Their amounts change with seasonal changes (Mbui *et al*., 2016). Population growth and the accompanying urbanization have led to insufficient management of wastes. Thus, wastes from domestic sources, industries and human waste end up into the Nairobi River. Mbui and coworkers (2016) studied the Nairobi River water pollution. The results of the study indicated higher levels of EC, pH, TSS, DO, phosphates and sulphates during wet as compared to the dry season. However, COD and BOD were higher during the dry season compared to wet season due to reduction of the water level (Mbui *et al*., 2016).

In Athi- Galana- Sabaki tributaries, research carried out on heavy metals in water and tilapia fish showed that Pb, Cd Mn and Cr levels in water were higher than WHO (2010) recommended limits. Mn, Ni and Pb in fish gills were higher than the recommended levels by the same organization. The study results indicated that the water and the fish were not suitable for human use (Muiruri and Nawiri, 2013). Rupingazi River in Embu is one of the main water sources for farming and household activities for the communities living near this the river. Its water quality analysis revealed that there are significant differences in parameter levels depending on seasons. In dry season, pH and temperature levels are above those in wet season. DO, turbidity, TDS, TSS and nitrates are greater in wet than in dry season (Bonareri *et al*, 2017). Most rivers in Tharaka-Nithi County originate from Mt Kenya. Increase in population and a wide range of anthropogenic activities like intensive agriculture, is affecting the water quality negatively. The results of an investigation on status of Naka River water in wet and dry seasons indicated that levels of chromium, manganese, aluminium and lead were beyond the maximum recommended levels by WHO, 2006. These results suggest that water from this river is unfit for human consumption. It was concluded that there is need for to be educative programs to the local people to create awareness on measures to safeguard the water (Ombaka *et al*, 2012).

2.3 Effects of Water Pollution

Water pollution effects vary and depend on the type and quantity of the pollutants. With the ever-increasing exponential growth of population, the increase in need for clean water and the pollution of water, there are serious engineering environmental challenges ahead. It is therefore necessary that economic development is carried out with utmost creativity and sensitivity (Ghouri and Member, 2010). In humans, consuming polluted water in any way has many disastrous effects to their health. Toxins from industrial wastes cause reproductive failure, immune suppression and acute poisoning. Consuming polluted water can give rise to spread of communicable diseases such as typhoid fever, cholera and other illnesses like diarrhoea, gastroenteritis, vomiting, skin diseases and kidney problems. Human wellness is negatively influenced directly by damage of plants and animals (Juneja & Chaudhary, 2013). Heavy rainfall and floods due to extreme weather can create environments suitable for different diseases in developed and developing countries. Water borne infections are mostly linked to fecal contamination of water sources (Haseena *et al*., 2017).

Some chemicals in water cause health problems to human beings. Examples are heavy metals namely: lead, arsenic, cadmium, mercury and other chemicals such as chlorinated solvents, petrochemicals, nitrates and pesticides. Arsenic is highly dangerous as it causes respiratory diseases, and arsenic skin lesions, resulting from drinking contaminated water. Lead metal affects CNS, blood and the kidneys. Mercury has been found to cause chromosomal aberrations and results in neurological damage to humans (Verma, 2017). Nutrient enrichment in water bodies causes eutrophication due to the excessive growth of algae species and plants. This occurs when nitrogen and phosphorus find their way into water. Detergents and industrial wastes cause phosphate enrichment in water bodies. The phosphates are absorbed by plants through the roots and surface absorption. They cause retardation in the growth of the plants, root elongation, carbon (iv) oxide fixation, chlorophylls and cell membranes destruction, as well as denaturing proteins causing enzyme inhibition in the metabolic processes of the plants (Huq *et al*., 2013).

Eutrophication leads to decrease in oxygen amounts in water leading to death of aquatic organisms. The chemical contaminants increase in aquatic or terrestrial environments, and are absorbed by plants through their roots (Chapman, 1996). Remains of excess agrochemical application to crops are washed away with rain water runoff. They find their way into the soil and end up in water bodies. This results to eutrophication which results to oxygen depletion in water bodies thereby causing death to aquatic animals (Chapman, 1996). Water bodies contain aerobic and anaerobic micro-organisms. When too much organic matter enters the water bodies, there is increased growth of micro-organisms. This leads to depletion of oxygen causing anaerobic organisms to thrive while the aerobic ones die. As the anaerobic organisms grow more, they release harmful toxins like ammonia and sulphides into the water (Juneja and Chaudhary, 2013). Nitrogen and phosphate containing fertilizers cause eutrophication.

Ammonium fertilizers are acidic. When they end up into water bodies, they cause water acidity hence lower water pH. In addition, herbicides, pesticides and insecticides affect the pH of water. They affect the rate of photosynthesis; may also cause oxidative phosphorylation uncoupling or inhibiting nitrate reductase enzymes. The uptake and bio-accumulation capacities of these substances are enhanced greatly in macrophytic plants as a result of their low solubility (Kamble, 2014). Acidic water has low population of microorganisms like bacteria and fungi. This lowers the decomposition rate of organic matter affecting the nutrient cycling process. The critical pH for microorganisms is 6.0. Some species decline below this while the acidic tolerant species increase. Multiplication of filamentous algae results to formation of a thick mat at the initial phase of water acidification. Green algae are destroyed at a pH below 5.8. It is observed that short root systems plants are severely affected by acidic water while those with deep roots and rhizomes are more tolerant to acid water (Kamble, 2014).

Some pollutants such as particulate matter exist as suspended material in water. They later settle under the water bodies. They bury fish eggs and fish nursery areas thereby interfering with chain. Rapid organic matter decomposition increase nutrients which favor increased growth of planktonic blue-green and green algal blooms which lead to the reduction of penetration depth of light into deeper layers of the water body with gradual decline of the flora submerged and growing in deep depths (Huq *et al.*, 2013). High levels of pollutants lead to increased COD, TDS, TSS, heavy metals and fecal coliforms. This makes water unsuitable for irrigation, drinking and aquatic life. Waste waters and chemical wastes from industries contain pollutants which cause high BOD levels leading to pollution and therefore causing unsuitability of the water for human use (Juneja and Chaudhary, 2013).

When pollutants enter the water bodies, they disrupt the food chains. This occurs when toxins from pollutants are taken in aquatic animals like fish which are later on consumed by humans. Pollutants disturb the food chains and affect growth of aquatic animals. For example, iron an example of heavy metal, interferes with the respiratory systems of fish (Leju *et al*., 2018). The contaminated fish are then consumed by humans causing health issues to them (Kamble, 2014). Thermal pollution has led to aerobic decomposers' reduction in activity due to depletion of oxygen in the water bodies because of high temperature. This jeopardizes the nutrients availability in the water bodies thereby reducing photosynthesis due enzyme activity inhibition with increase in water temperature. The overall effect of thermal pollution is decrease in primary diversity and productivity of aquatic plant species (Huq *et al*., 2013).

2.4 Analytical Techniques

2.4.1 Spectrophotometric determination of metals

Quantitative determination of the levels of parameters in sediment and water samples can be achieved using various techniques. In this study, AAS was employed for analysis of Pb, Fe, Mn and Cd. The method was selected because it is devoid of poly atomic interference and is less affected by suppression of the matrices (Mbui, *et al.*, 2018). It is also a simple, sensitive, fast method and of low cost. Before the analysis, the samples were acid digested with concentrated nitric acid. This is done since all nitrate salts are soluble and to destroy the matrix (Kanyaru, 2018).

2.4.2 Working principle of AAS

AAS measures the radiation that is emitted or absorbed by atoms or ions of an element. An atom has a positively changed nucleus that is surrounded by negatively charged electrons. The electrons move around it in energy levels. When the electrons absorb or emit sufficient energy, they change their energy level. Such transitions are accompanied by energy changes which are characteristic to specific elements (Solano, 2013). The change in the intensity of light radiation from the initial to the final intensity is measured. The change in the radiation intensity increases with increase in concentration of atoms in a sample. This is guided by Beer Lambert’s law. The law states that, absorbance directly proportional to sample path length and concentration of analyte (Solano, 2013).

$A = \mathcal{E}\, b\, C,$

Where A is the absorbance, $\mathcal{E}$ is the molar absorption coefficient, b is path length and c is the analyte concentration.

2.4.3 UV–VIS spectroscopy

UV-VIS technique and ion exchange chromatography are used for inorganic species analysis such as phosphates, nitrates and halides (Kanyaru, 2018, Shaikh *et al*., 2016). In this research, UV-VIS was selected for the analysis of nitrates and phosphates. The technique was chosen since it is fairly simple, takes short time, and data analysis is also simple.

2.4.4 Working principle of UV- VIS spectroscopy.

Bonding electrons interact with radiation in the UV- Visible region. The electrons are promoted from one orbital to another. The absorbed radiation corresponds to the amount energy required to promote the electrons from one orbital to another and is unique to different types of bonds in compounds. The amount of the analyte of interest in a sample is calculated using the law of photometry;

$$A = k\ c\ l$$

Where A is absorbance, k is a constant known as molar absorptivity, c is the concentration and L is the path length. This implies that absorbance is directly proportional to the concentration. Calibration curves are used to determine the concentration of the parameter (Solano, 2013).

2.4.5 Physical parameters Analysis

Physical parameters were measured using respective meters. Temperature and pH of water were obtained by use of pH meter during the time of sampling, electrical conductivity using conductivity meter and turbidity using turbidity meter. TDS and TSS were analyzed using standard procedures described by APHA, 2011.

2. 5 Physical and Chemical parameters

Awareness of the levels of chemical and physical variables of water helps to understand the quality status of water in the available water sources. The amount of these variables is influenced by the quantity of the inorganic and organic matter present in the water source (Bonareri *et al*., 2017). Examples of the chemical and physical parameters include electrical conductivity, , turbidity, temperature, TSS, TDS, DO, COD, BOD, Phosphates, Nitrates, alkalinity, heavy metals and hardness. The physical parameters investigated in this study are as follows.

2.5.1 pH

It is the measure of the hydrogen ion (H^+) concentration in in a solution expressed as – log [H^+]. Water pH is altered by release of detergents, presence of algal blooms, agricultural runoff and presence of limestone. It decreases with increase in temperature since at high temperature water dissociates giving more hydrogen ions (Marina *et al*, 2013). It affects the levels of nutrients, heavy metals, biological activity and solubility of substances in water (Ombaka *et al*., 2013).

2.5.2 Temperature

The level of temperature influences both chemical and biological processes in a given water body. Such processes include decomposition of matter, solubility of substances, and electrical conductivity. High temperatures influence growth rate of aquatic plants and animals and also pH. Changes in water temperature are brought about by sunlight, runoff, deforestation and climatic conditions of an area where the water body is situated (Islam *et al.*, 2015 and Huq *et al*., 2013).

2.5.3 Electrical conductivity (EC)

It is the measure of the ability of water to conduct an electric current. Electrical conductivity is measured in Micro- Siemens per centimeter and increases with increase in number of dissolved ions in the water (WHO, 2011). It measures the amount dissolved ionic substances measured in water. The ions come from dissolved salts such as chlorides, carbonates, nitrates, sulphides and alkalis. High levels of dissolved substances affect the taste of water and may lead to salinity when used for irrigation (Bonareri *et al*., 2017).

2.5.4 Turbidity

This measures the relative clearness of a liquid. It is the degree to which a transparent liquid scatters or disperses light. It measures the amount suspended matter in a liquid. Turbidity of water is affected by levels tiny organic and inorganic matter, algae, silt, clay, mud and microscopic organisms. The particles scatter light and make the water appear murky. High turbidity may shield bacteria and prevent effective water treatment through chlorination. It may cause clogging in water pipes and also staining. It may also increase water temperature since suspended particles absorb more light. In humans, high turbidity may cause nausea and headaches (Bonareri *et al*., 2017).

2.5.5 Total Suspended Solids (TSS)

This refers to mass of dry solids not dissolved in a sample of water. It includes suspended clay, sand, bacteria, gravel and silt. It is measured in mg/ L. It is brought about by erosion and runoff, algae, sediment disruption among others. High TSS decreases natural DO, is responsible for high water turbidity and may affect human health. It makes water treatment techniques ineffective. Sand and silt may bring about aesthetic issues in pipes and fittings and water-based appliances (Leju *et al*., 2018).

2.5.6 Total Dissolved Solids (TDS)

This refers to the amount of total solid materials dissolved in a litre of water. It is the sum of all particles which are less than 0.0002 cm. It is usually expressed in mg/ L. Dissolved materials may include ionized forms, molecular forms or micro- granular form (Ombaka *et al*., 2012 and Juneja and Chaudhary, 2013). The causes of high levels of TDS include run off, industrial sewage and wastes, silt and plankton among others. High levels of TDS in water affect human health. It may cause nausea, vomiting, dizziness, rushes and lung irritation. It leads to soap wastage when used for laundry, stains household fixtures and corrodes pipe when the dissolved substances are calcium and magnesium salts (Juneja and Chaudhary, 2013).

2.6 Chemical parameters

The chemical parameters encompass metals and nutrients. They are investigated in both water and sediment samples. Levels metallic parameters are investigated using AAS while those of phosphates and nitrates were measured using UV-VIS spectrometry.

2.6.1 Heavy metals

They are elements with high densities due to high atomic masses. They are naturally occurring metallic elements. They have comprehensive applications and this explains their wide distribution in the environment. Some of the heavy metals have high toxicity. Some are carcinogenic and at low levels of concentration cause multiple organ damage (Bonareri *et al*., 2017).

2.6.1.1 Lead

Lead is the one of the commonest heavy elements and takes up 13mg/kg of the earth's surface. It is a general toxicant in young children up to six years old and in pregnant women. It is toxic to both the peripheral and central nervous systems (Saeed *et al.,* 2014). Lead for example inhibits enzyme activity at concentrations of 10 Ng / 100 ml. It interferes with blood metabolism and reduces formation of red blood cells thereby leading to anemia. It replaces calcium in bones. It is introduced into water bodies from agricultural runoff, industrial wastes and volcanic eruptions (Verma, 2017).

2.6.1.2 Cadmium

It is another toxic heavy metal at low concentrations. It causes overproduction of reactive oxygen pesticides which causes damage to cell bio-molecules and organelles. It also causes damage to plant membranes. It is carcinogenic and causes kidney, blood, liver and bones damage on long term exposure. It is introduced into water from fertilizers, rock weathering, mining and waste discharges (Saeed *et al*., 2014).

2.6.1.3 Manganese

It is commonly used in manufacture of manganese compounds which have a wide range of applications for example in fertilizers, batteries, glass and fireworks (WHO, 2011). Manganese can find its way into water from industrial activities, rock weathering and mining. It affects the color of water. In its oxidized state, it gives water a black tint. It leads to clogging of water systems and stains clothes and kitchenware (Bonareri *et al*., 2017).

2.6.1.4 Iron

It is naturally occurring, metallic element in the soil, ground water and in many types of rocks. It occurs naturally in rivers and may be released into water from refining of iron ores, industrial wastes, natural deposits and corrosion of iron containing materials. Large quantities of iron in human body cause health problems such as damage to the kidney and the liver. It also affects the color of food and water. In its oxidized state, it gives water a brown color. It can also cause staining of kitchen utensils and cloths. Iron may also cause clogging of water systems (Bonareri *et al*., 2017).

2.6.2 Anions

Phosphate is the oxidized form of phosphorus and may occur in living and decaying plant and animal materials. Phosphates are introduced to water bodies through various ways. These may include detergents, industrial and domestic discharges, surface runoff and over use of phosphate fertilizers and wastes containing animal and human waste, soil erosion and phosphate containing rocks. High levels of phosphates cause eutrophication and affects process of water treatment. It may also lead to algal blooms which produce algal toxins that are harmful to animal and human health (Huq *et al*., 2013).

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2.6.2.2 Nitrates

This is the oxidized form of nitrogen. Levels of nitrate are increase in river water from several sources. Some of these sources include manure, nitrogenous fertilizers, sewage and agricultural runoff. When the nitrate levels in water is above 10 mg /L, the water is said to be polluted (WHO, 2011). Drinking water with high nitrate levels may cause blue baby disease in infants. It is also harmful to respiratory and reproductive systems, kidney, spleen and thyroid (Kamble, 2014).

2.7 Biological parameters

2.7.1 Total coliform

They are bacterial organisms present in the digestive tracts of animals and human beings. They are found in their wastes. They are also present in soil and in surface water. Although they don’t cause illnesses, they are indicators of water pollution. They enter into water bodies from storm water run-off, domestic animals and wildlife, untreated sewage and septic discharges and animal manure (Singh &Sao, 2015).

2.7.2 Fecal coliforms

This is a part of total coliform bacteria found specifically in the feces and intestines of endotherms (Kithaka *et al.*, 2020). When fecal coliforms are present in water, they cause diseases like diarrhea (Haseena *et al.*, 2017).

2.8 Summary of the research gap

Natural processes and human activities influence the quality of water by introducing unwanted substances into the water bodies. The introduced substances alter the levels of water parameters. This affects the status of water in the affected water bodies. The levels of water parameters should be monitored regularly using the available methods in order to make sure it is fit for use by humans and animals and also for other uses. This can be done through investigation of the levels of the physical, chemical and biological factors. Mutonga River passes through different climatic zones where small-scale farming takes place, extensive quarrying is practiced and other activities are carried out. The quality of water in the river is likely to be affected severely. The water is used for domestic and irrigation purposes and also by animals hence quality is important. There is no documented research on levels of physical, chemical and biological parameter along the river. This study was aimed at filling the research gap.

CHAPTER THREE: MATERIALS AND METHODS

3.1 Research design

In this study, experimental research design was applied which was achieved through laboratory experiments. Purposeful sampling was used. Analysis techniques used were verified, and the collected samples put through laboratory tests and *in-situ* measurements. The data collected was applied to statistical analysis to determine whether there were significant differences in levels of parameters aiming the sites and between seasons.

3.2 Study Area

Mutonga is located at the boundary between two Counties, Tharaka –Nithi County which borders Embu County in the south and Meru County in the South West. Tharaka -Nithi County is located between latitude 00°07′and 00°26′and longitudes 37°19′and 37°46′ East. County of Meru lies between 00°6′North and 00°1′ South Latitudes and 37^{o} West and 38^{o} East longiudes. Mutonga river springs from Mt Kenya and proceeds eastwards via varied zones. Various human activities are carried out along the river for food production and income generation through quarrying. Figure 3.1 and 3.2 shows the map of the study area and location of sampling points respectively.

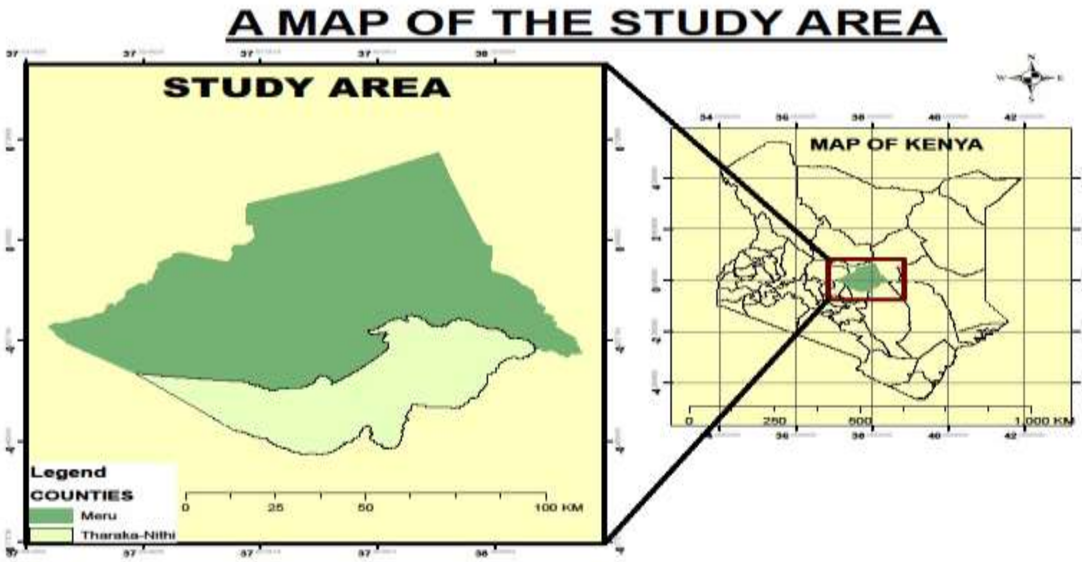


Figure 3.1: Location of the study area

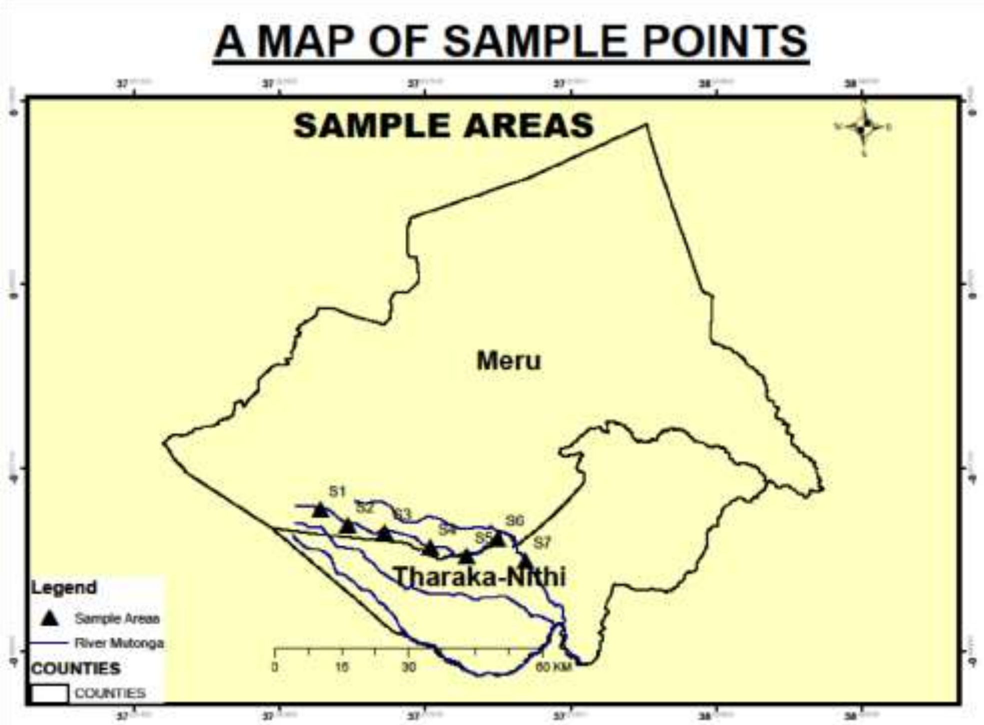


Figure 3.2: Location of Sampling Points

Source: http//mapsof.net/map/Kenya-topography

KEY

S1 (LS1) – Sampling point 1, S2 (LS2) – Sampling point 2, S3 (LS3) –Sampling point 3, S4 (LS4) - Sampling point 4, S5 (LS5) – Sampling point 5, S6 (LS6) – Sampling point 6 and S7 (LS7) – Sampling point 7

Mutonga River flows from Mt Kenya through Meru County eastwards before entering in Tharaka- Nithi County. Along the river, there is small scale agriculture which involves planting of crops such as kales and tomatoes, coffee and tea, maize and beans and also bananas. Such crops require farm chemicals, fertilizers, and farmyard manure. Extensive quarrying is practiced along the river with high usage of manual power and machines for stone cutting. People also practice livestock rearing and in the lower parts of the river the animals are watered directly from the river.

3.3 Sample collection

Purposeful sampling was done. Samples were picked from the selected sampling sites in areas with different human activities. Water and sediments samples were collected in early October for dry season and late November for the wet season. For determination biological parameters, water samples were taken using bottles which had been treated with sodium thiosulphate to neutralizing any chlorides that may be in the river water (Kithaka *et al*., 2020). Polyethylene terephthalate containers were used to fetch water for analysis of chemical parameters. The bottles were treated with dilute hydrochloric acid then rinsed thoroughly with deionized water. They were finally rinsed with river water before sampling. For metal analysis, bottles were treated with Nitric acid before sample collection (APHA, 2010). The collected samples were carried in opaque boxes packed with ice packs to maintain them at a temperature below 10℃ (APHA, 2010) and taken to the laboratory for analysis. An improvised Auger sampler was employed for collection sediment samples which were transported using plastic bags (Ondoo *et al*., 2020).

3.4 Chemicals and Reagents

All chemicals used in this study were of analytical grade. Where necessary, the chemicals were diluted using distilled water. These chemicals were sodium hydroxide (99%), nitric (V) acid (69%), hydrochloric acid (35-38 %), sulfuric (VI) acid (98 %), ascorbic acid, acetic acid (94%), ammonium sulphate (98.5%), sodium chloride (99.5%) and distilled water. The chemicals were obtained from suppliers who connected to LOBA chemical ltd in India.

3.5 Instrumentation

Analysis of metals was done using AAS PG 900 while that of anions was done using UV-VIS spectrometer (UV 1800A, Shimadzu). The systems' operating wavelengths are shown in the Table 3.1 (Ombaka et al., 2012).

Table 3.1: Operating wavelengths for AAS AND UV-VIS spectrometers

Parameter	Operating wavelength (nm)
Pb	217.0
Cd	288.5
Fe	248.3
Mn	279.5
PO_{4} -	840 .0
NO_{3}-	220.0

3.6 Method validation

The validation of AAS and UV-VIS methods was determined using recovery tests. Water samples were spiked with 2ppm of standard solutions containing the analytes of interest. Blanks, spiked and unspiked samples of water were analyzed. The results were used to calculate the percentage recovery. The following equation was used (Solano, 2017).

$$\% \text{ Recovery} = \frac{S-U}{A}$$

Where S is the concentration of the spiked sample, U is the concentration of the unspiked sample and A is the concentration of the spiking standards

For AAS and UV-VIS calibration curves were drawn and used to find out the amounts of analytes in water and sediment samples. Calibration for each heavy metal was carried out by sequential dilution of commercial stock of 1000 mg/L concentration. The ranges of dilutions depended on the metal. For cadmium it was 0.1-0.5ppm, for lead it was 0.1 - 8.0 ppm, for iron was 0.5 -10.0 and that of manganese was0.5-8.0ppm. For the UV-Vis analysis, the dilutions were 0.1- 0.8 ppm and 0.2-10ppm for phosphates and nitrates respectively. Blank and standard solutions were analyzed in triplicates.

3.7. Analysis procedures

3.7.1 Analysis of physical parameters

Temperature and pH of water were recorded *in situ* using a transportable pH meter of temperature compensation 25ºC (APHA, 2010). Before the measurements, the meter was calibrated with pH buffers of pH 4.0, 7.0 and 10.0. The pH meter electrodes were placed in the buffer solution and stable value was set. Electrical conductivity was measured in the laboratory using HANNA- EC 215 conductivity meter. The meter was calibrated using deionized water and a standard of 100 ppm sodium chloride. The calibrated meter was immersed into water samples and stable reading taken and recorded in triplicate. Turbidity was determined using HANNA H193703 turbidity meter. Its calibration was done using distilled water and a standard of 100 NTU.

3.7. 2.Analysis of anions in water

3.7.2.1 Nitrates

Fifty ml of blank solution, calibration standards and samples were prepared. One milliliter of a molar hydrochloric acid added to each. The mixtures were subjected to UV -VIS for analysis. A calibration curve was drawn to determine the concentration of nitrate ions in the samples.

3.7.2.2 Phosphates

Fifty ml water samples, blanks, calibration standards were prepared and 2ml of ascorbic acid buffer added to each. The resulting solutions were kept undisturbed for 10 minutes and the absorbance of each was read off from a UV/VIS spectrometer (Samuel *et al*., 2017).

3.7.3 Analysis of anions in sediments

3.7.3.1: Analysis of Phosphates

Exactly 2.50 grams of a sample from each site was weighed using MS204s/01 analytical balance. 50 ml of 0.80 molar sodium hydrogen carbonate was added. The resulting mixture was placed on mechanical shaker and shaken for 30minutes then left for 6 hours. The combination was then filtered-off using what man filter paper number 1. Resulting solution was made up to 50 ml using a volumetric flask and left to settle for about 30 min then analyzed using UV-VIS machine at 400 nm (Ondoo *et al*., 2020).

3.7.3.2 Analysis of nitrates

Exactly 1.00g of each sample was taken and put into 50 ml of distilled water. Then the mixture was maintained undisturbed for 6 hrs. The resulting mixture was filtered, one ml of one molar hydrochloric acid added to the filtrate and shaken for ten min and 15 ml of distilled water added. Three drops of nitro-phenol indicator were added followed by a solution of ammonia until yellow color appeared. After thirty minutes the solution was subjected to UV-VIS spectrophotometer for a read out to be taken (Bonareri *et al*., 2017).

3.7.4 Analysis of heavy metals in water and sediments

Metals in water and sediments were analyzed using AAS procedures (Muiruri, 2013). Three hundred milliliters of sample were measured, 50%concentrated nitric (v) acid added and the solution heated on a hot plate until the water evaporated leaving about 50 ml. The hot solution was allowed to cool and filtered to remove all undissolved material. Distilled water was added to make up a 100 ml volume which was used for analysis. Sediment samples were homogenized in a mortar using a pestle. Nine millimeters of concentrated nitric (v) acid was added to 0.2 g of ground sample and 3 ml of concentrated hydrochloric acid was then added. The mixture was placed in an Ethos Easy microwave digester for 45 min then allowed to cool. It was then filtered and the filtrate was made up to 50 ml by and used for analysis (Ondoo *et al*., 2019).

3.7.5 Analysis of Total and fecal coliform content in water

Levels of TC and FC were determined by MPN method. MacConkey violet Broth was used (Ogunbode *et al*., 2016). One ml of diluted water sample was used to inoculate an already prepared culture media. The mixture was then maintained for 48 hours at 37.5^0C for TC and 44^0C for FC analysis after which counts were analyzed (Kithaka *et al*., 2020).

3.8 Statistical analysis

The *Median* values for the physical and chemical parameters were analyzed using SAS software for windows version 9.4, where Kruskal Wallis test was used to obtain significant differences between levels by site and by season at $p < 0.05$. The data obtained for these parameters was non-parametric. This means the data did not show normal distribution. For the levels of biological parameters, (ANOVA) test was used for the determination of the significant differences by site and season. The collected data was parametric and assumed normal distribution. Further post hoc tests were carried out after the Kruskal Wallis and ANOVA to determine where values varied significantly between sites.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

The findings of the investigation on the levels of parameters in water and sediment samples along Mutonga River are presented in this chapter. Tables and graphs were used to present the results as per the study objectives. Significant differences between levels of parameters were determined using Kruskal Wallis test for physical and chemical parameters and ANOVA test for biological parameters.

4.2 Methods Validation

The calibration curve for iron is given in Figure 4.1 and that of phosphates is given in Figure 4.2. The calibration parameters are given in Table 4.1 together with the percentage recovery. All the percentage recoveries were between the allowed range of 80- 120 % making the methods reliable and accurate as shown in the table (Muiruri *et al,* 2013).

Table 4.1: Method validation parameter results for metals and anions

Parameter	r^2	Regression line	% Recovery
Pb	0.99897	A=0.0100C+0.0017	99.55
Cd	0.98745	A=0.3994C- 0.0109	98.99
Fe	0.99925	A= 0.0259C-0.0009	116.20
Mn	0.77724	A =0.044C-0.0018	97.85
PO_{4} -	0.99068	A=0.53465C+0.00734	97.68
NO_{3}-	0.99728	A =0.05301C+0.01620	100.7

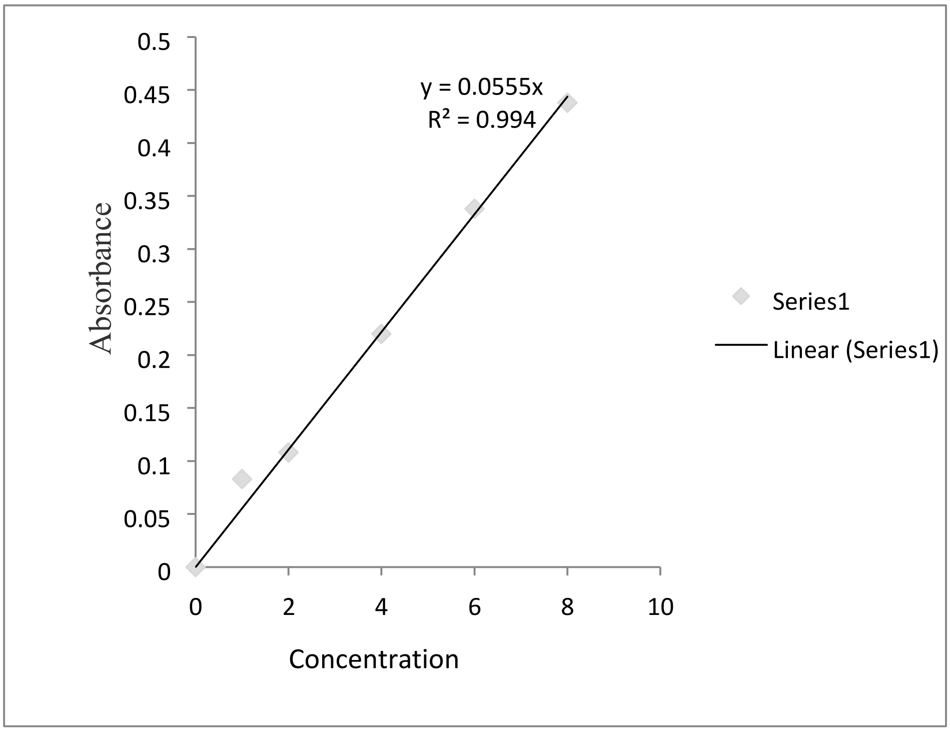


Figure 4.1 Calibration curve for iron

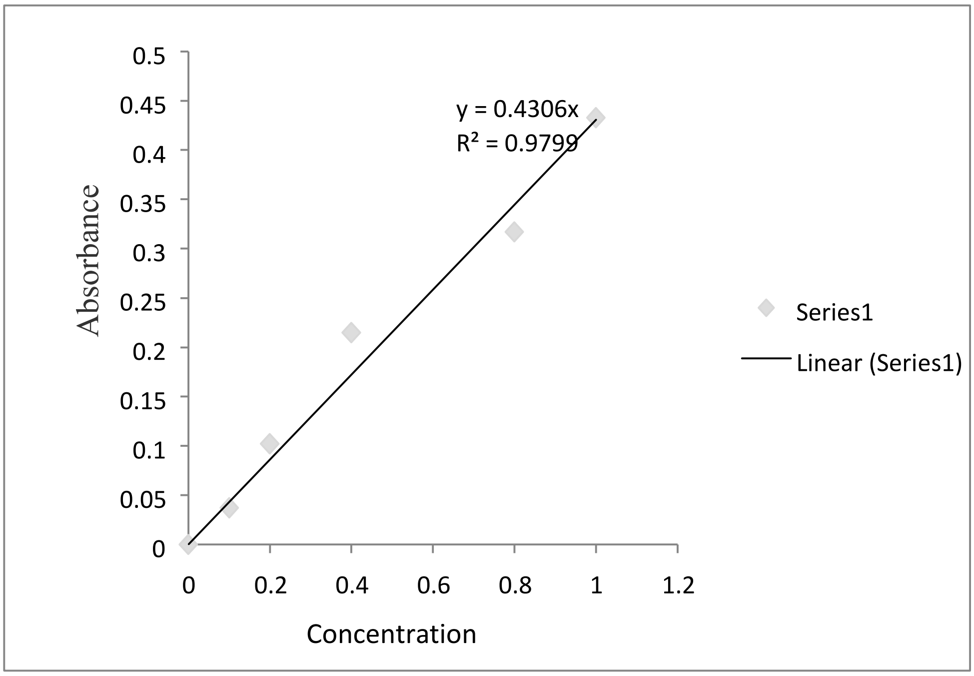


Figure 4.2: Calibration curve for phosphates

According to Wasike, *et al*, 2019 r values for Pb, Cd, and Mn were 0.9947, 0.9992 and 1.000 respectively. When r values are closer to 1, method used for analysis is able to give accurate results. From the standard calibration curves, the correlation coefficient values indicated show strong linear relationship between absorbance and concentration levels of parameters (Muiruri, *et al*, 2013).

4.3 Physical parameters in water

Their means plus standard deviations values are presented in Table 4.2.

4.3.1 The pH

A pH value of 7 is considered to be the best and most ideal for drinking water (Ombaka *et al.*, 2012). The ranges of pH values along the sampling locations were 5.67 ±0.00 to 6.15±0.06 in dry season. This is an indication that the river water is weakly acidic. This could be attributed to agricultural activities along the river which involve use of acidic inorganic fertilizers (Brian *et al.*,2011) and decomposition of organic matter which releases acidic carbon (IV) oxide into the water (Bonareri *et al.*, 2017). In wet season, mean values were slightly above those in dry season. Their range was (6.48 ±0.03 - 7.74±0.16). The slight increase was significant (table 4.3). This could be attributed to surface runoff which may introduce alkaline matter into the water thereby neutralizing some of the H^+. The observed pH values were higher in wet than dry season. The results agree with those of a study carried out on Naka River in Tharaka Nithi County (Ombaka *et al.*, 2012). WHO, 2011 proposes a 6.5 to 8.5 range of pH for water for various purposes. This implies that water along River Mutonga is unsuitable for human and animal use in dry season.

Table 4.2: Levels (Mean± SD) of physical parameters in the dry and wet seasons

Site		Parameters					
		pH	TEMP (º C)	EC (µS/cm)	TURB (NTU)	TSS (ppm)	TDS (ppm)
LS1	Dry	6.05	13.50	0.43	14.89	71.33	206.33
		±0.06	±0.10	±0.15	±2.18	±12.90	±2.08
	Wet	6.48	17.00	44.47	64.67	112.67	247.3
		±0.16	±0.10	±0.12	±4.51	±25.40	3±1.15
LS2	Dry	5.70	15.10	0.30	17.71	94.67	224.0
		±0.01	±0.00	±0.10	±4.70	±5.14	±291.01
	Wet	7.10	16.30	43.87	75.33	100.33	142.0
		±0.29	±0.10	±0.06	±3.06	±17.67	±2.0
LS3	Dry	6.05	19.80	0.13	21.94	38.33	152.00
		±0.06	±0.00	±0.06	±3.78	±3.21	±1.0
	Wet	6.71	18.40	35.93	129.00	103.67	264.0
		±0.34	±0.10	±0.58	±1.00	±6.66	±4.00
LS4	Dry	6.15	20.07	0.27	25.60	56.00	60.0
		±0.15	±0.06	±0.06	±3.09	±12.77	±1.00
	Wet	6.84	18.50	36.10	325.00	105.33	266.0
		±0.01	±0.00	±0.17	±0.00	±25.54	±4.0
LS5	Dry	5.92	20.47	0.20	34.38	47.00	29.33
		±0.00	±0.06	±0.10	±3.03	±9.54	±2.31
	Wet	6.65	18.30	35.60	141.00	142.33	444.0
		±0.18	±0.00	±0.00	±3.00	±38.53	±287.52
LS6	Dry	5.67	25.00	0.30	37.99	52.33	59.67
		±0.00	±0.00	±0.00	±0.84	±46.18	±0.58
	Wet	6.66	18.50	93.50	203.33	142.00	17.0
		±0.31	±0.10	±0.10	±3.06	±25.53	±1.00
LS7	Dry	5.76	26.60	0.40	26.11	66.67	125.33
		±0.09	±0.10	±0.00	±2.27	±49.12	±0.58
	Wet	7.74	20.73	44.60	1000.67	132.00	229.67
		±0.03	±0.55	±0.10	±1.15	±19.97	±1.53

It is noted that the mean values increase along the river in the two seasons. Lowest values were recorded down- stream at site LS6 and highest at LS2 up-stream. The lower value can be attributed to presence of small-scale horticultural farming activities which involves usage of a lot of inorganic fertilizers (Bonareri *et al*., 2017). The higher value may be due release of remains of quarrying activities since the site is located within a quarry site (Ombaka *et al*., 2012).

The results of water pH in different locations may be associated with actions such as mining, farming and laundry along the river. According to Bonareri *et al.,* 2017, agricultural activities along a river influence water pH. Significant differences of water pH were recorded between seasons ($p<0.05$). The pH values were higher (6.48) during the wet season and were lower in the dry season (5.95) as shown in Figure 4.3. These results resemble those of Rupingazi River Kenya where there was higher pH in the wet season. Differences in pH between seasons may be brought about by factors that include rainfall and drought leading to varied concentrations of hydrogen ions.

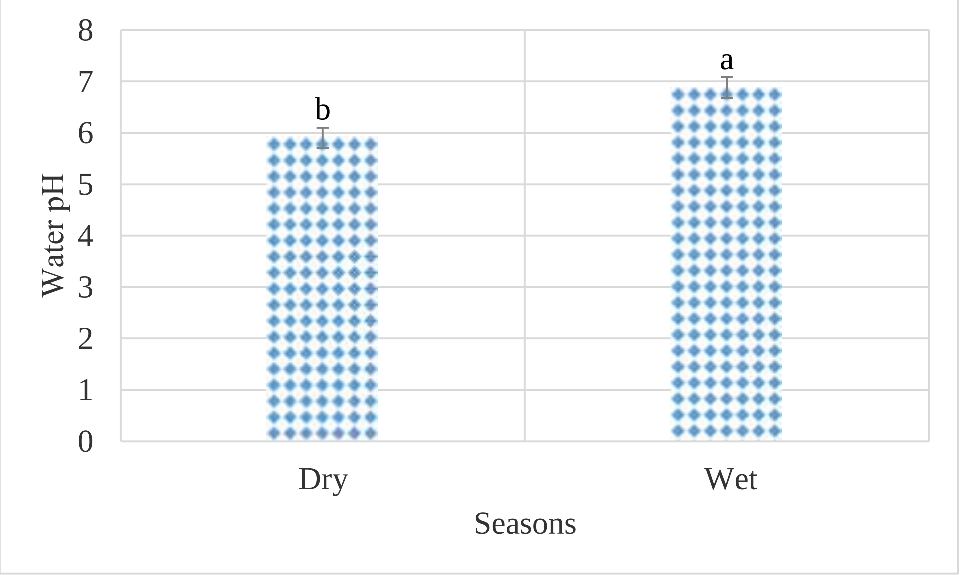
A significant difference in values of pH ($p < 0.05$) was observed among the sampling locations during the dry season ($p = 0.0051$). The highest value of pH was at location LS4 with a *Median* of 6.32 and was lower at location LS6 with *Median* of 5.67 (Table 4.3). During the wet season, significant differences ($p > 0.05$) were observed on pH values among the locations ($p = 0.0128$) as shown in Table 4.3. Similar observations were seen on river Rupingazi by Bonareri et al. (2017). The recorded pH values were below the WHO 2011 permissible levels of between 6.5-8.5 all of the sites except at LS7 in wet season.

Table 4.3: Analyzed values of water pH in sampling locations per season

Seasons	Location	Means±SD	*Median*	Minimum	Maximum	Kruskal walis
	LS1	6.22 ±0.27	6.12 ab	6.01	6.52	
	LS2	5.70±0.01	5.70 ^{c}	5.69	5.71	
	LS3	6.05±0.06	6.05 bc	6.00	6.11	H = 18.484 p = 0.0051
Dry	LS4	6.32±0.01	6.32 ^{a}	6.31	6.33	
	LS5	5.92±0.0	5.92 ^{cd}	5.92	5.92	Df= 6
	LS6	5.67±0.0	5.67 ^{c}	5.67	5.67	
	LS7	5.76±0.09	5.77 ^{dc}	5.67	5.85	
	LS1	6.48±0.16	6.45 ^{b}	6.34	6.65	
	LS2	6.44±0.87	5.94 ^{b}	5.93	7.44	
	LS3	6.04±0.24	5.92 ^{b}	5.89	6.32	H = 9.915 p = 0.0128
Wet	LS4	6.17±0.58	5.84 ^{b}	5.83	6.84	
	LS5	5.98±0.52	5.86 ^{b}	5.54	6.55	Df = 6
	LS6	6.53±0.90	6.32 ^{b}	5.75	7.52	
	LS7	7.74 ±09	7.74 ^{a}	7.71	7.76	N = 3
	H =6.3304			p =0. 012	Df= 1	

where SD = standard deviation, LS= Location, three samples were analyzed for each location
N = sample size, values followed by similar letters as superscript are not significantly different

The pH of water samples along the river differed significantly ($p < 0.05$) with the season (H (42) = 30.541, p <.0001). The wet season had significantly higher pH values (*Median* = 6.84) than the dry season (*Median*= 5.92) Figure 1) as observed by Kaniz *et al*., (20 14). Figure 5 shows the variation in the *Median* values of pH among the sites during the wet and the dry season.



Letters a and b show that values were significantly different.

Figure 4.3: Means of the pH of water during the dry and wet season

4.3.2 Temperature

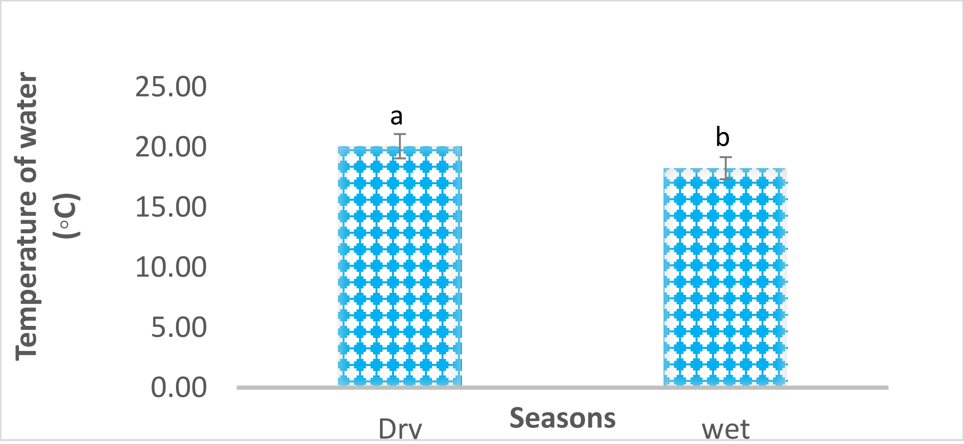
The temperature ranges in dry season were 13.50± 0.10 to 26.60 ± 0.10 ^{o} c and in wet season they were 16.30±0.10 – 21.73 ±0.55 this is within the allowed limit by WHO. These findings are likened to those observed by Ombaka *et al.*, 2012 and 2013 on Ruguti and Naka River respectively. Decrease in water levels leads to less solubility of matter which absorbs heat energy from the sun. This makes water hotter in dry than wet season. The outcome of this study agrees with results of a similar study carried out on Padma River in Bangladesh (Ayenuddin *et al*., 2018). The lower values in wet season could be due to to cloudy conditions where amount of thermal radiation penetrating such atmospheric conditions is limited. The high temperature in the river is also responsible for aquatic community's destruction and further interferes with the water purification process. Temperature is not a linear parameter in time and space therefore limited standards are applied for domestic use (Mbui, *et al*., 2016).

Values of temperature had significant differences ($p < 0.05$) in all the sampling locations during the dry season (H (21) = 19.816, $p = 0.003$). Temperatures values differed significantly ($p < 0.05$) between some of the sampling location (H (21) = 18.718, $p = 0.005$) during wet season with significantly higher and lower values being at LS7 (*Median* = 21°C) and LS1 (16.90°C) respectively (Table 4.4). This agrees with results of Kaniz *et al.*, (2014). Values followed by similar letters did not vary significantly as shown in table 4.4. Those with different letters varied significantly. Water temperature along River Mutonga differed significantly ($p = 0.05$) between the seasons (H (42) = 3.2477, $p = 0.0715$). However, dry season had slightly higher water temperature (*Median*= 20.09◦C) as compared to temperature of water during the rainy season, (*Median* = 18.27˚C) Figure 4.4]. Similar observations were made by Kimani *et al.*, (2016). The observed values are not above WHO levels of range12 to 25°C except on site Ls7 which is located in a semi-arid zone.

Table 4.4: Analyzed values of temperature in sampling locations per season

		Temperatures of water (°C)				
Seasons	Location	Means±SD	*Median*	Minimum	Maximum	Kruskal - Walis
Dry	LS1	13.50±0.10	13.50^{a}	13.40	13.60	
	LS2	15.10±0.00	15.10^{b}	15.10	15.10	
	LS3	19.80±0.00	19.80^{c}	19.80	19.80	H =19.816
	LS4	20.07±0.06	20.10^{d}	20.00	20.10	p = 0.003
	LS5	20.47±0.06	20.50^{e}	20.40	20.50	Df= 6
	LS6	25.00±0.00	25.00f	25.00	25.00	
	LS7	26.60±0.10	26.60^{g}	26.50	26.70	
Wet	LS1	17.00±0.10	17.00^{c}	16.90	17.10	
	LS2	16.30±0.10	16.30^{d}	16.20	16.40	
	LS3	18.40±0.10	18.40^{b}	18.30	18.50	H =18.718
	LS4	18.50±0.00	18.50^{b}	18.50	18.50	p = 0.005
	LS5	18.30±0.00	18.30^{b}	18.30	18.30	Df = 6
	LS6	18.50±0.10	18.50^{b}	18.40	18.60	N=3
	LS7	20.73±0.55	21.00^{a}	20.10	21.10	
	H =31.297			p< 0.0001	Df= 1	
	where SD= standard deviation, N = Sample Size					

Values followed by similar letters are not significantly different



Letters a and b indicate values were significantly different

Figure 4.4: Mean levels of water temperature in the dry and wet seasons

4.3.3 Electrical conductivity

Electrical conductivity is the measurement of the capability of a solution to allow flow current through it. This ability is dependent on availability of mobile ions, their amount, and temperature of the solution. Inorganic compounds relatively good conductors in solution form while organic compounds are molecules that do not ionize in aqueous solution therefore, they are poor conductors or insulators. The conductivity water from Mutonga River ranged between 0.10 to 0.60 and 35.60 to 93.50 µS/cm during dry and wet season, respectively. The ranges are in agreement with those observed along Ruguti River (Ombaka *et al*., 2012). The observed levels of conductivity were not above the WHO values prescribed for drinking purposes which is 1500 µS/cm. The larger values of electrical conductivity in wet season could be related to pollution from surface runoff water, which washes waste material carrying soluble minerals into rivers and also due to increased ionization of ionic substances with increased water volume in the river during this season (Oduor et al., 2020).

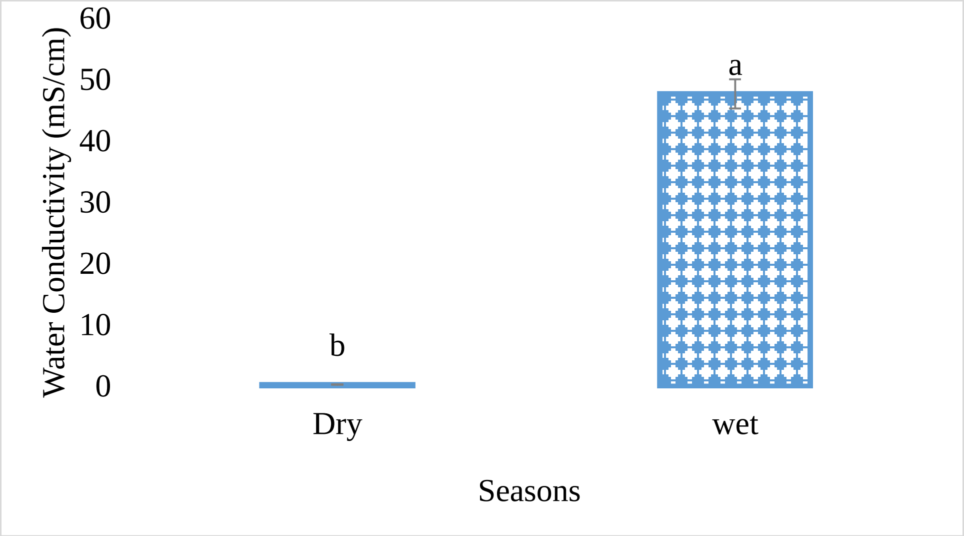
The electrical conductivity was highest at site 6, which can be associated with anthropogenic activities such garbage dumping, washing of clothes and weathering of sediments or mineralization (Ombaka et al., 2012). Water conductivity along River Mutonga had significant differences ($p < 0.05$) among the sampling locations during the dry season (H (21) = 14.271, $p = 0.027$) as observed by Kaniz *et al*., (2014). Higher conductivity value was observed at location LS1 and LS7 which had similar *Median* of 0.40µS/cm while lower conductivity values was recorded in location LS3 with *Median* of 0.10µS/cm. Water conductivity values in wet season differed significantly ($p < 0.05$) among the sampling locations (H (21) = 18.957, $p = 0.0042$) (Bonareri *et al*., 2017). Conductivity values were significantly higher at location LS6 (*Median* = 93.40mS/cm) and was lower at LS3 and LS5 which had equal *Median* (*Median* = 35.6µS/cm) respectively (Table 4.5).

Table 4.5: Analyzed values of water E C in sampling locations per Season

		Conductivity of water (mS /cm)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal-wallis
Dry	LS1	0.43±0.15	0.40^{ab}	0.30	0.60	
	LS2	0.30±0.10	0.30^{ab}	0.20	0.40	
	LS3	0.13±0.06	0.10^{cd}	0.10	0.20	H =14.271
	LS4	0.27±0.06	0.30^{bc}	0.20	0.30	*p* = 0.027
	LS5	0.20±0.10	0.20^{bd}	0.10	0.30	Df= 6
	LS6	0.30±0.00	0.30^{bd}	0.30	0.30	
	LS7	0.40±0.00	0.40^{a}	0.40	0.40	
Wet	LS1	44.47±0.12	44.40^{b}	44.40	44.60	
	LS2	43.87±0.06	43.90^{c}	43.80	43.90	
	LS3	35.93±0.58	35.60^{de}	35.60	36.60	H =18.957
	LS4	36.10±0.17	36.00^{d}	36.00	36.30	*p* = 0.0042
	LS5	35.60±0.00	35.60^{de}	35.60	35.60	Df = 6
	LS6	93.50±0.10	93.50^{a}	93.40	93.60	
	LS7	44.60±0.10	44.60^{b}	44.50	44.70	N = 3
	H =7.2204			*p* = 0.3009	Df= 1	

where SD= standard deviation, N =Sample size, values followed by similar letters are not significantly different

Water conductivity along River Mutonga differ significantly ($p < 0.05$) between the seasons (*H* (42) = 31.1256, $p < 0.0001$). Water conductivity was higher during wet season (*Median* = 43.9 µS/cm) as compared to dry season (*Median* = 0.3µS/cm) Figure 4.5. This can be attributed to surface run off which carries dissolved salts into the water as well as increased water volume which causea easier ion mobility (Faryal *et al*., 2014 and Kaniz *et al*., 2014).



Letters a and b show values were significantly different

Figure 4.5: Mean levels of water conductivity in the dry and wet season

The higher conductivity levels in wet season can be attributed to increased volume of water which causes dilution thereby causing easier mobility of ions (Oduor *et al.*, 2020) and surface runoff that carries more ionic compounds into the river as observed on river Rupingazi (Bonareri *et al.*, 2017).

4.3.4 Turbidity

The mean values of turbidity ranged from 14.89 ±2.18 to 37.99±0.84 and 64.47 ±4.57 to 1000± 0.67 NTU in dry and wet season respectively. Higher turbidity levels were observed at LS6 in dry season and LS7 in wet season. Variations in turbidity levels from different points of sampling may be brought about by differences in the nature of the particulates at sampling points (Ombaka *et al.*, 2012). Mean values of turbidity were higher during wet season and may be due to increased stream flow, surface run off, and overland flow which increase amount of suspended matter. The obtained turbidity levels in this work were higher than those described by WHO (5 NTU) in the two seasons which is a sign of water pollution. Similar observations were made on River Sio (Ondoo *et al.*, 2019). The turbidity of water differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 17.766, p = 0.0068) (Osei *et al.*, 2008). Higher value of turbidity was recorded at location LS6 with a *Median* of 38.05NTU and was lower in location LS1 with *Median* of 14.04 NTU (Table 4.6).

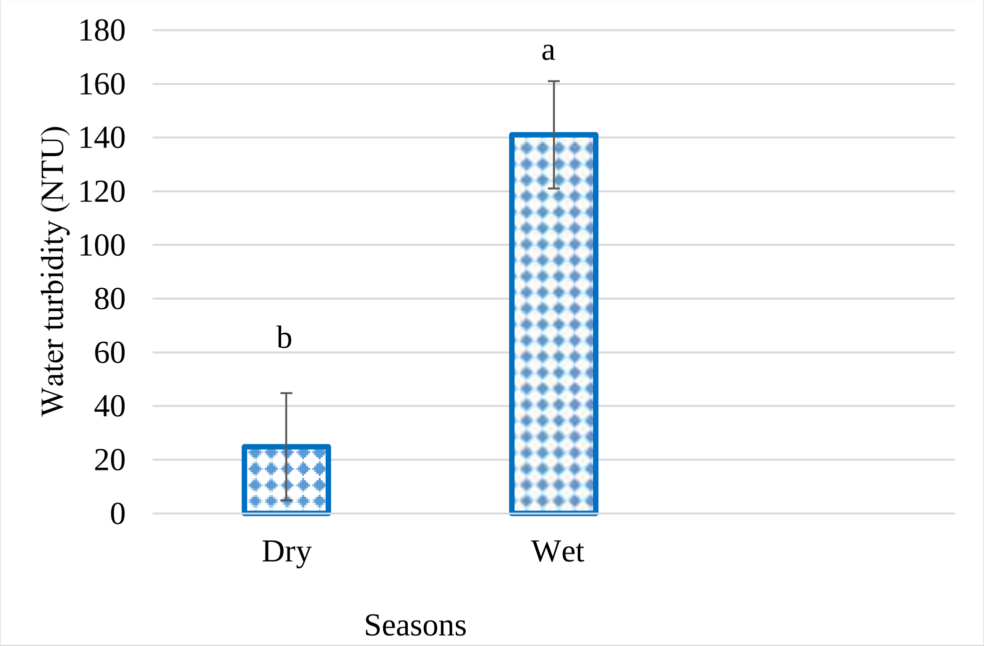
Table 4.6: Analyzed values of water Turbidity in sampling locations per Season

		Turbidity of water (NTU)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal wallis
Dry	LS1	14.89±2.18	14.04^{d}	13.26	17.36	
	LS2	17.71±4.70	15.73^{cd}	14.33	23.08	
	LS3	21.94±3.78	23.30^{bc}	17.67	24.86	H =17.766
	LS4	25.60±3.09	26.58^{bc}	22.14	28.08	p = 0.0068
	LS5	34.38±3.03	34.26^{a}	31.42	37.47	Df= 6
	LS6	37.99±0.84	38.05^{a}	37.12	38.79	
	LS7	26.11±2.27	25.62^{b}	24.13	28.58	
Wet	LS1	64.67±4.51	65.00^{g}	60.00	69.00	
	LS2	75.33±3.06	76.00^{f}	72.00	78.00	
	LS3	129.00±1.00	129.00^{e}	128.00	130.00	H =19.7003
	LS4	325.00±0.00	325.00^{b}	325.00	325.00	p = 0.0031
	LS5	141.00±3.00	141.00^{d}	138.00	144.00	Df = 6
	LS6	203.33±3.06	204.00^{c}	200.00	206.00	
	LS7	1000.67±1.15	1000.00^{a}	1000.00	1002.00	N = 3
	H =7.937			p = 0.243	Df= 6	

where SD = standard deviation, N = Sample size, values followed by similar letters were not significantly different

During the wet season, water turbidity values differed significantly ($p < 0.05$) among the sampling location (H (21) = 19.7003, p = 0.0031). The turbidity values were significantly higher at location LS7 (*Median* = 1000NTU) and was lower at LS1

(*Median* = 65NTU). The turbidity of water differed significantly (*H* (42) = 31.1256, *p* < 0.001) between seasons. Water turbidity was significantly higher during wet season (*Median*= 141NTU) when compared to dry season [(*Median*= 24.86 NTU) Figure 4.6] as observed on Mabork estuary in Malaysia (Kaniz *et al*., 2014).



Letters a and b indicate values differ significantly

Figure 4.6: Mean levels of water turbidity in the dry and wet seasons

4.3.5 Total suspended solids

Solids include suspended and dissolved matter in water bodies. Dissolved solids are mainly ionic salts, small amount of organic matter and gases dissolved in water. An increase in TSS increases the extent of pollution in water. TSS refers to the dry weight of solids not dissolved in a sample of water (Bonareri *et al*., 2017). Along Mutonga River, TSS mean values ranged from 38.33±3.21 to 94.67±5.14 in dry season and 100.33±17.77 -142.00 ±25.33 in the wet season. Most values were above 75mg/kg proposed limit by WHO. The higher level at location LS2 can be attributed to presence a quarry site that is closest to the river which introduces particles of quarry processes into the river. In the wet season, values can be related to water turbulence, mixing and higher flow rate of water which makes the distribution of particles almost uniform (Oremo *et al*., 2018).

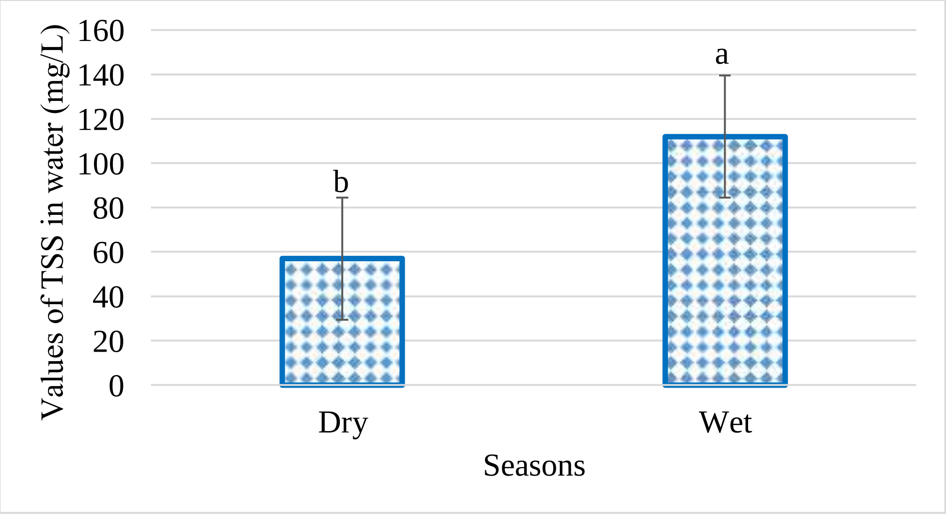
The TSS of water did not differ significantly ($p > 0.005$) among the sampling locations along River Mutonga during the dry season (H (21) = 6.6103, $p = 0.3584$). However, slightly higher value of TSS was recorded at location LS2 with a *Median* of 85 mg/Land was lower in location LS5 with *Median* of 37mg/L (Table 8). No significant ($p > 0.05$) differences were observed in the TSS values among the sampling location (H (21) = 8.7153, $p = 0.1902$) during the wet season. This matched with the observations of Boukari *et al*., 2016. Nonetheless, location LS5 had slightly higher values of TSS (*Median* =144mg/L) and was lower in location LS1 [(*Median*= 98mg/ L) (Table 4.7)].

Table 4.7: Analyzed values of water TSS in sampling locations per Season

		Total suspended solid of water (mg/L)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal wallis
Dry	LS1	71.33±12.90	75.00	57.00	82.00	
	LS2	94.67±55.14	85.00	45.00	154.00	
	LS3	38.33±3.21	37.00	36.00	42.00	H =6.6103
	LS4	56.00±12.77	59.00	42.00	67.00	$p = 0.3584$
	LS5	47.00±9.54	48.00	37.00	56.00	Df= 6
	LS6	52.33±46.18	57.00	4.00	96.00	
	LS7	66.67±49.12	93.00	10.00	97.00	
Wet	LS1	112.67±25.40	98.00	98.00	142.00	
	LS2	100.33±17.67	109.00	80.00	112.00	
	LS3	103.67±6.66	102.00	98.00	111.00	H =8.7153
	LS4	105.33±25.54	107.00	79.00	130.00	$p = 0.1902$
	LS5	142.33±38.53	144.00	103.00	180.00	Df = 6
	LS6	142.00±25.53	136.00	120.00	170.00	
	LS7	132.00±19.97	122.00	119.00	155.00	N = 3
	H =2.6006			$p = 0.857$	Df= 6	

where SD = standard deviation, N = Sample size

The TSS in water along River Mutonga differed significantly ($p < 0.05$) between the seasons (H (42) = 23.4629, $p < 0.0001$). Nevertheless, no significant differences were noted in TSS among the sites in both seasons. The TSS was higher during wet season (*Median*= 112 mg/L) as compared to dry season [(*Median*= 57 mg/L) Figure 4.7] (Bonareri *et al*., 2017).



Letters a and b show values differ significantly between seasons

Figure 4.7: Mean levels of water TSS in the dry and wet season

4.3.6 Total dissolved solids

TDS in samples of water ranged from 17.00 ± 1.00 to 224.00±0.01 mg/L in dry season. The range was 29.33 ± 2.31 - 444.00 ± 287.52mg/L in wet season. This concurs with results of a study on Nairobi River (Mbui *et al*., 2016 and Ondoo *et al.*, 2019). These high values can be related to high number of quarrying sites which involve both manual and machine power. These values were below the drinking standard set by WHO 2011. The rise in the TDS in wet season can be attributed to contamination through drainage and discharge of domestic waste into the river (Bonareri *et al*., Mbui *et al*., 2016). Levels of total dissolved solids up to 500 mg/L in water generally make it suitable for domestic use. Water with higher content up to 1500 mg/L are also acceptable, however they may sometimes lead to producing some physiological effects on the human system unless it gets adopted after some use.

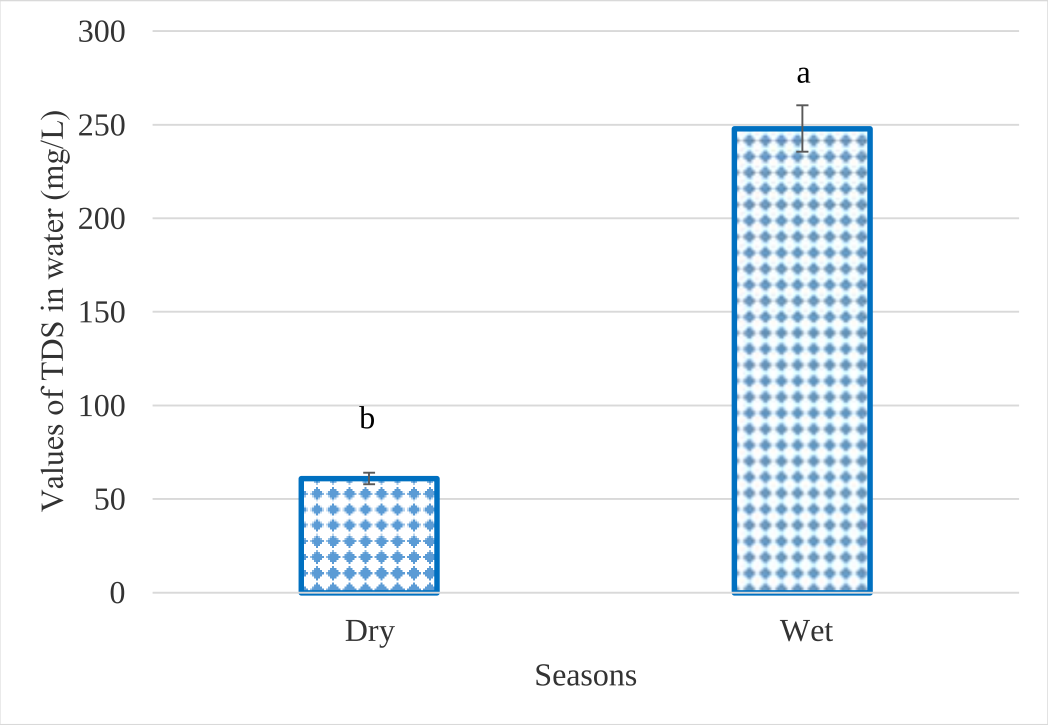
The total dissolved solids in water samples from Mutonga River fluctuated from site to site. The range was 29.33 ± 2.31 – 206.33 ± 2.08 in dry season and 142.00 ± 2.00 – 444.00 ± 287.52 in the wet season). This can be related to the difference in the activities and nature of the conditions surrounding the sampling location (Mbui *et al.*, 2016). The values were below the drinking water standard set by WHO 2011. The TDS of water differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 15.1976, p = 0.0188). Higher value of TDS was recorded at location LS1 with a *Median* of 207 and was lower in location LS5 with *Median* of 28 (Table 4.8). A significant ($p < 0.05$) difference was observed in the TDS values among the sampling locations (H (21) = 270.3498, p = 0.0036) during wet season. Similar observations were made on Rupingazi River (Bonareri et al., 2017). Location LS5 had higher values of TDS (*Median* = 278mg/L) and was lower in location LS6 [(*Median* = 17mg/L) Table 4.8). The increase in dissolved solids total in the wet season can be related to pollution through the surface runoff and discharge of domestic waste into the river (Oduor, 2020).

Table 4.8: Analyzed values of water TDS in sampling locations per Season

Seasons	Location	Total dissolved solid in water (mg/L)				Kruskal Wallis
		Means±SD	Median	Minimum	Maximum	
Dry	LS1	206.33±2.08	207.00ab	204.00	208.00	
	LS2	224.0±291.01	60.00ab	52.00	560.00	
	LS3	152.00±1.0	152.00ab	151.00	153.00	H =15.1976
	LS4	60.0±1.00	60.00ab	59.00	61.00	*p* = 0.0188
	LS5	29.33±2.31	28.00b	28.00	32.00	Df= 6
	LS6	59.67±0.58	60.00c	59.00	60.00	
	LS7	125.33±0.58	125.00b	125.00	126.00	
Wet	LS1	247.33±1.15	248.00b	246.00	248.00	
	LS2	142.0±2.0	142.00bc	140.00	144.00	
	LS3	264.0±4.0	264.00ab	260.00	268.00	*H* =19.3498
	LS4	266.0±4.0	266.00ab	262.00	270.00	*p* = 0.0036
	LS5	444.0±287.52	278.00a	278.00	776.00	Df = 6
	LS6	17.0±1.0	17.00c	16.00	18.00	
	LS7	229.67±1.53	230.00b	228.00	231.00	N = 3
	H =13.3501			*p* = 0.0378	Df= 6	

where SD = standard deviation, N = Sample size, values with similar letters don't differ significantly

Season had a significant difference ($p < 2.05$) on the TDS values recorded (*H* (21) = 9.5077, $p = 0.002$) during wet season. Wet season had higher values of TDS (*Median* = 248mg/L) compared to dry season [(*Median* = 61mg/L) Figure 4.8].



Letters a and b show values were significantly different

Figure 4.8: Mean levels of water TDS in the dry and wet season

4.4: Chemical parameters in water

The section presents the comparison between the mean and SD levels of chemical parameters in water during dry and wet season.

Table 4.9: Levels (Mean ±SD) of chemical parameters in water in the two seasons

Site		Parameters					
		Lead (ppm)	Cadmium (ppm)	Iron (ppm)	Manganese (ppm)	Nitrates (ppm)	Phosphate (ppm)
LS1	**Dry**	BDL	BDL	0.27 ±0.02	BDL	1.33 ±0.00	0.247 ±0.00
	Wet	0.03 ±0.00	BDL	2.37 ±0.05	0.05 ± 0.00	2.36 ±0.00	0.797 ±0.00
LS2	**Dry**	BDL	BDL	0.37 ±0.01	BDL	1.13 ±0.00	0.816 ±0.00
	Wet	0.04 ±0.01	BDL	2.98 ±0.08	0.07 ±0.01	2.59 ±0.00	4.217 ±0.06
LS3	**Dry**	0.14 ±0.02	BDL	0.47 ±0.20	BDL	1.20 ±0.01	0.312 ±0.00
	Wet	0.12 ±0.06	BDL	2.20 ±0.03	0.10 ±0.01	3.20 ±0.00	0.945 ±0.06
LS4	**Dry**	).16 ±0	BDL	0.61 ±0.01	BDL	1.43 ±0.00	0.223 ±0.00
	Wet	0.09 ±0.01	0.002 ±0.00	5.94 ±0.08	0.11 ±0.00	3.59 ±0.00	0.421 ±0.12
LS5	**Dry**	BDL	BDL	0.59 ±0.02	BDL	1.15 ±0.00	0.519 ±0.00
	Wet	0.09 ±0.00	0.003 ±0.00	7.65 ±0.13	0.07 ±0.06	4.01 ±0.00	0.965 ±0.00
LS6	**Dry**	0.29 ±0.03	BDL	0.56 ±0.01	BDL	3.83 ±0.00	0.525 ±0.00
	Wet	0.10 ±0.01	BDL	6.11 ±0.13	0.14 ±0.01	3.83 ±0.00	0.843 ±0.00
LS7	**Dry**	0.14 ±0.02	BDL	0.56 ±0.03	BDL	0.49 ±0.00	
	Wet	0.22 ±0.02	0.001 ±0.00	2.40 ±0.55	2.22 ±0.06	3.97 ±0.03	0.746 ±0.00

Sd – standard deviation;*BDL stands for below detection level

4.4.1 Lead

The range of lead levels was 0.00 to 0.29± 0.031 during dry season. In wet season the range was 0.03±0.00 to 0.22±0.02. The values were above WHO limit(0.1mg/l) in most locations. The levels differed significantly between seasons. This agrees with the result of an assessment of water in other Kenyan rivers (Mbui *et al.*, 2016 and Ombaka, *et al.*, 2012). The levels of Pb in water differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season agrees with results of Mwangi, 2013, (H (21) = 18.6103, $p = 0.0049$). Higher value of Pb was recorded at location LS6 with a *Median* of 0.27ppm. This can be attributed to small-scale agricultural activities which make use of inorganic fertilizers (Mbui *et al.*, 2016) and was below detectable levels in locations LS1, LS2 and LS5 (Table 4.10) (Ombaka *et al*., 2012). A significant difference ($p < 0.05$) was noted in the Pb values among the sampling location (H (21) = 16.9331, $p = 0.0095$) during wet season (Muiruri *et al*, 2013). Location LS7 had higher values of Pb (*Median* = 0.22ppm) while location LS1 had lower values of Pb [(*Median* = 0.01ppm) Table 4.10

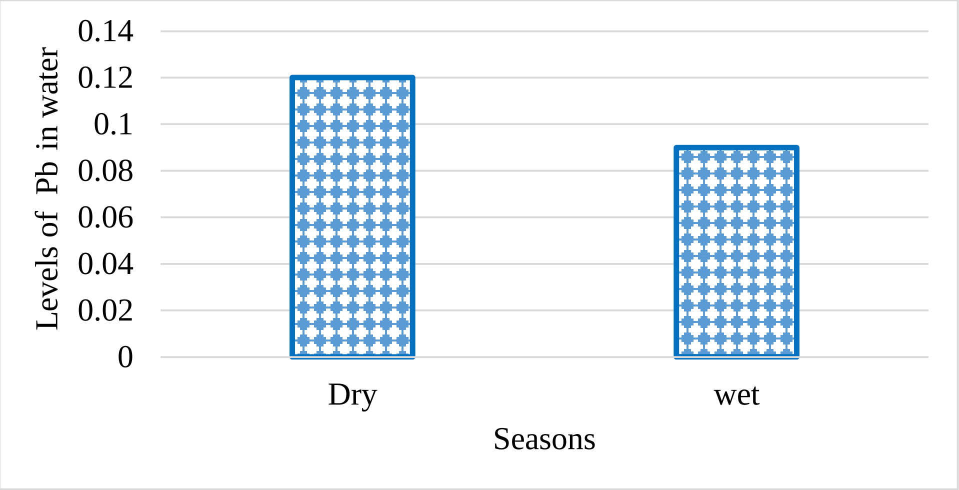
Table 4.10: Analyzed values of Pb in Water in sampling locations per Season

		Values of Pb (ppm)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal Wallis
Dry	LS1	BDL	0.00^{c}	0.00	0.00	
	LS2	BDL	0.00^{c}	0.00	0.00	
	LS3	0.14±0.02	0.14^{b}	0.11	0.16	H =18.6103
	LS4	0.16±0	0.16^{b}	0.16	0.16	p = 0.0049
	LS5	BDL	0.00^{c}	0.00	0.00	Df= 6
	LS6	0.29±0.03	0.27^{a}	0.27	0.32	
	LS7	0.14±0.02	0.13^{b}	0.12	0.16	
Wet	LS1	0.03±0.00	0.03^{c}	0.03	0.03	
	LS2	0.04±0.01	0.04^{c}	0.03	0.05	
	LS3	0.12±0.06	0.15^{b}	0.05	0.16	H =16.9331
	LS4	0.09±0.01	0.09^{b}	0.08	0.10	p = 0.0095
	LS5	0.09±0.00	0.09^{b}	0.09	0.10	Df = 6
	LS6	0.10±0.01	0.10^{b}	0.09	0.11	
	LS7	0.22±0.02	0.22^{a}	0.19	0.24	N=3
	H =29.9612			p <.0001	Df= 1	

where BDL = Below detection levels (BDL was assumed to be zero for the purpose of analysis), SD = standard deviation, N = Sample size, values with similar letters don't differ significantly

Season had no significant ($p > 0.05$) effect on the Pb values in water samples (H (21) = 0.0518, p = 0.82ppm) during wet season. This agrees with results Minhaz *et al.*

2019.Nonetheless, dry season had slightly higher values of Pb (*Median* = 0.12ppm) compared to wet season [(*Median*=0.09) Figure 11] (Mihaz *et al*., 2019).



Letters a and b show values differ significantly

Figure 4.9: Mean levels of Pb in water during the dry and wet seasons

4.4.2 Cadmium

Cadmium was below the detection limit in water samples from all the sites in dry season. This complied with results of a study carried out on water samples from Ruguti River (Ombaka *et al*., 2012). This can be due to the fact that cadmium may precipitate as carbonates or get adsorbed onto organic and particulate matter at the bottom sediments. In the wet season, Cd was detected in three sampling sites. This could be due to surface run off (Mbui *et al*., 2016) and entry of rain water containing atmospheric cadmium (Ombaka *et al*., 2012 and Wasike et al, 2019).

4.4.3 Iron

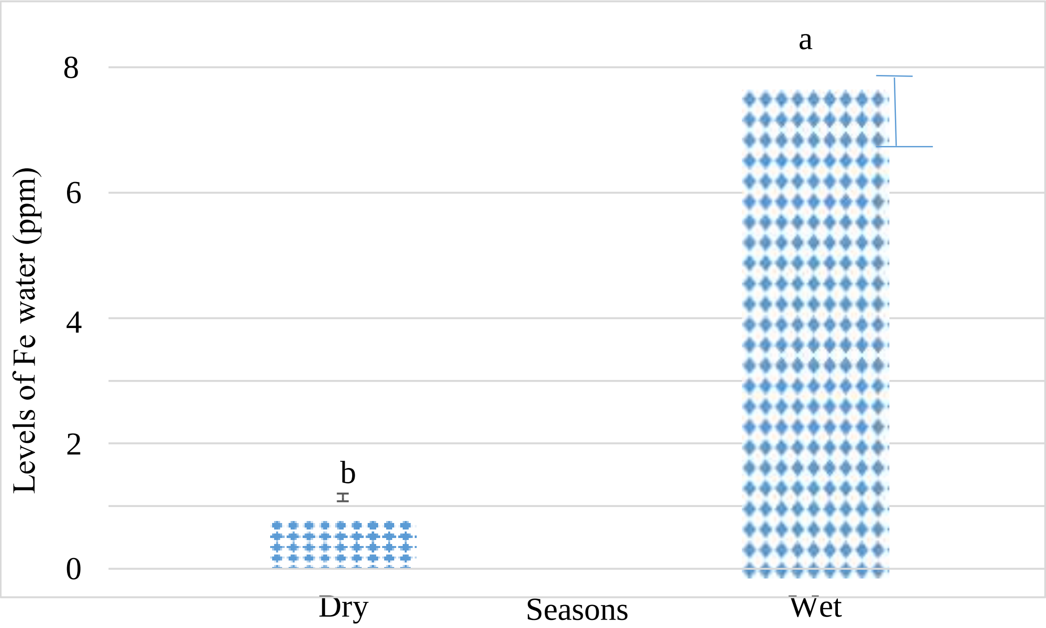
Iron levels had a range of 0.27±0.02 – 0.61± 0.01 in dry season and 2.20 ±0.03 7.65±0.13 in wet. This observation is similar to other research work on other rivers and can be attributed to iron rich soils along the river (Mwanzia *et al*., 2019). Higher levels were recorded in wet season. This could also be due to surface run-off which carries iron rich soils into the water and increased solubility of iron compounds releasing more iron into the water body (Ombaka *et al*., 2012 and Wasike, 2017). The values of Fe in water differed significantly ($p < 0.05$) in all the sampling locations along the river during the dry season (H (21) = 14.1569, $p = 0.0279$). Higher values of Fe were recorded at location LS4 with a *Median* of 0.58ppm and was low in location at LS1 [(*Median* = 0.28ppm) Table 4.11]. During the wet season significant differences ($p > 0.05$) were observed in the Fe values among the sampling location (H (21) = 17.9048, $p = 0.0065$) during wet season. However, location LS5 had higher values of Fe (*Median* = 7.7ppm) while location LS3 had slightly lower Fe (*Median* = 2.19ppm) values (Table 4.11). Values of Fe were above WHO permissible limit (0.3mg/l) in all sites except LS1 in dry season.

Table 4.11: Analyzed values of Fe in Water in sampling locations per Season

Location		Values of Fe (ppm)				Kruskal Wallis
		Means	*Median*	Minimum	Maximum	
Dry	LS1	0.27±0.02	0.28^{c}	0.26	0.29	
	LS2	0.37±0.01	0.37^{bc}	0.36	0.38	
	LS3	0.47±0.20	0.57^{ab}	0.24	0.61	H =14.1569
	LS4	0.61±0.01	0.61^{a}	0.59	0.62	$p = 0.0279$
	LS5	0.59±0.02	0.58^{a}	0.58	0.61	Df= 6
	LS6	0.56±0.01	0.57^{a}	0.54	0.57	
	LS7	0.56±0.03	0.57^{a}	0.53	0.60	
Wet	LS1	2.37±0.05	2.39^{d}	2.32	2.41	
	LS2	2.98±0.08	2.99^{c}	2.90	3.05	
	LS3	2.20±0.03	2.19^{d}	2.18	2.23	H =17.9048
	LS4	5.94±0.08	5.91^{b}	5.89	6.03	$p = 0.0065$
	LS5	7.65±0.13	7.70^{a}	7.50	7.74	Df = 6
	LS6	6.11±0.13	6.09^{b}	6.00	6.26	
	LS7	2.40±0.55	2.10^{d}	2.06	3.04	
	H =6.1472			$p = <.0001$	Df= 1	

where Std= standard deviation, N = Sample size

Season had significant ($p < 0.05$) effect on the Fe values in water (H (21) = 30.7724, $p < 0.0001$) during wet season. The values of Fe were higher in the wet season (*Median* = 3.04 ppm) as compared to dry season [(*Median* = 0.57ppm) Figure 4.10). This agrees with results in Nzhelela River (Joshua *et al*., 2017).



Letters a and b indicate values differ significantly

Figure 4.10: Mean levels of water Fe in the dry and wet season

4.4.4 Manganese

Level of manganese was below detectable limit in all water samples in dry season. However, it was found to have a mean range of 0.05±0.002 to 2.22±0.06 in wet season. The higher manganese values in wet season may associated to surface runoff which carries the element from agricultural land and dissolution of the element from geological rocks of unknown composition and release from sediments as well dumpsites of quarrying activities along the river (Mbui *et al*., 2016, and Saeed *et al*., 2014).

Table 4.12: Analyzed values of Mn in Water in sampling locations in wet Season

	Values of Mn^- (ppm)					
	Location	Means±SD	*Median*	Minimum	Maximum	Kruskal Wallis
	LS1	0.05±0.00	0.05^{c}	0.05	0.05	
	LS2	0.08±0.01	0.07^{bc}	0.07	0.08	
	LS3	0.11±0.01	$0,10^{b}$	0.10	0.11	H(21) =18.303
Wet	LS4	0.11±0.00	0.11^{b}	0.11	0.11	*p* = 0.0055
	LS5	0.08±0.06	0.11^{b}	0.01	0.11	df = 6
	LS6	0.14±0.01	0.14^{b}	0.04	0.15	N =3
	LS7	2.23±0.06	2.25^{a}	2.16	2,28	

where SD = standard deviation, N = Sample size, values followed by similar letters were not significantly different

The values for the Mn in water differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the wet season (*H* (42) = 18.303, $p = 0.0055$). Higher values of Mn were recorded at location LS7 with a *Median* of 2.25ppm. This may be attributed to accumulation as river flows and geology of the (Sultan *et al.*, 2011). It was low in location at LS3 [(*Median* = 0.01ppm) (Figure 4.11)]. The data collected for Mn in the dry season was not subjected to analysis since Mn level was below detectable limits in water samples from the seven sampling locations.

4.4.5 Nitrates

Surface runoff from agricultural land carries nitrates into water from fertilizers like CAN and also organic matter. This could explain the higher level of nitrates in wet season (range 2.36±0.00 – 4.01±0.00) as compared to that in dry season (range 0.49±0.00- 3.83±0.00) (Bonareri, 2017 and Ombaka *et al.*, 2012). The values for the NO_3^- in water differed significantly ($p < 0.05$) among the sampling locations along

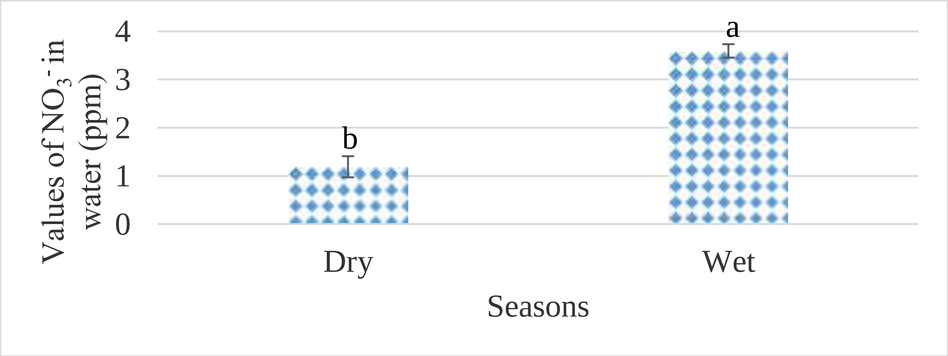
River Mutonga during the dry season (H (21) = 19.6747, p = 0.0032) (Ayennnudin *et al*., 2018). Higher value of NO_3^- was recorded at location LS6 with a *Median* of 3.83 ppm [(*Median* 0.49 ppm) Table 4.13] and may be due to the use of fertilizers by the farmers practicing small-scale irrigation in the area (Bonareri *et al*., 2017). During the wet season a significant ($p < 0.05$) difference in NO_3^- values in water was observed among the sampling location (Ezzat *et al*., 2012). (H (21) = 19.6619, p =0.0032). Location LS7 had higher values of NO_3^- (*Median* = 3.96 ppm) while location LS1 had lower NO_3^- (*Median* = 2.36 ppm) values (Table 4.13).

Table 4.13: Analyzed values of NO_3^- in Water in sampling locations per Season

Location		Values of NO_3^- (ppm)				
		Means±SD	*Median*	Minimum	Maximum	Kruskal Wallis
Dry	LS1	1.33 ±0.00	1.33^{c}	1.33	1.33	
	LS2	1.13±0.00	1.13^{f}	1.13	1.13	
	LS3	1.20±0.01	1.19^{d}	1.19	1.21	H =19.6747
	LS4	1.43±0.00	1.44^{b}	1.43	1.44	*p* = 0.0032
	LS5	1.15±0.00	1.15^{e}	1.15	1.15	df= 6
	LS6	3.83±0.00	3.83^{a}	3.82	3.83	
	LS7	0.49±0.00	0.49^{g}	0.49	0.49	
Wet	LS1	2.36±0.0	2.36^{g}	2.36	2.37	
	LS2	2.59±0.0	2.59^{f}	2.59	2.59	
	LS3	3.20±0.0	3.20^{e}	3.20	3.21	H =19.6619
	LS4	3.59±0.0	3.59^{d}	3.58	3.59	*p* = 0.0032
	LS5	4.01±0.0	4.01^{a}	4.01	4.01	df = 6
	LS6	3.83±0.0	3.83^{c}	3.83	3.84	
	LS7	3.97±0.03	3.96^{b}	3.95	4.00	N=3
	H =9.6916			*p* = <.0001	df= 1	

where SD = standard deviation, N = Sample size, values followed by different letters were significantly different

Season had significant ($p < 0.05$) effect on the NO_3^- values in water (H (21) = 21.549, p <0.0001) during wet season (Ayennudin *et al*., 2018). The values of NO_3^- was higher in the wet season (*Median* =3.59 ppm) as compared to dry season [(*Median* = 1.19 ppm) (Figure 4.12)].



Letters a and b show values differ significantly

Figure 4.11: Levels of water NO$_3^-$ in the dry and wet season

4.4.6 Phosphates

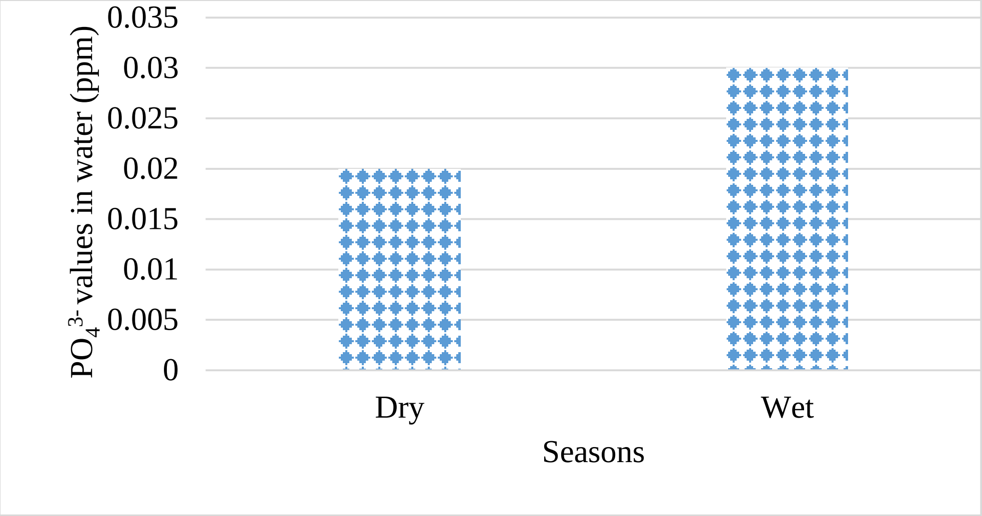
The levels of phosphates ranged from 0.247±0.00 to 0.818±0.001 in dry season and 0.421±0.115 to 4.27±0.058 in the wet. It was observed that the levels were higher in wet than dry season. This can be attributed to run-off from agricultural land which deposits water containing dissolved phosphate fertilizers and detergents into the river and from high rate of breakdown of organic matter (Bonareri *et al.*, 2017). The values for the PO$_4^{3-}$in water differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 19.9209, p = 0.0029) as observed by Fella *et al*, 2018. Significantly higher values of PO$_4^{3-}$were recorded at location LS2 with a *Median* of 0.03 ppm and was significantly lower in location at LS7 [(*Median* = 0.004 ppm) Table 4.14]. This can be associated to small scale agricultural which involves use of farmyard manure and inorganic fertilizers (Boukari *et al.*, 2016). During the wet season a significant difference ($p < 0.05$) in PO$_4^{3-}$ values in water was observed among the sampling locations (H (21) = 19.9209, p = 0.0029). The findings are in line with those of Ayennudin *et al.*, (2018). Location LS7 had higher values of PO$_4^{3-}$ (*Median* = 0.23 ppm) while location LS2 had lower PO$_4^{3-}$(*Median* = 0.002ppm) values (Table 4.14). The higher level can be due to surface run off and detergents since community people do their laundry directly into the river (Boukari *et al.*, 2016).

Table 4.14: Analyzed values of PO_4^{3-} in Water in sampling locations per Season

Location		Values of PO_4^{3-}(ppm)				Kruskal wallis
		Means±SD	*Median*	Minimum	Maximum	
Dry	LS1	0.023±0.0	0.023^{b}	0.023	0.023	
	LS2	0.03±0.0	0.030^{a}	0.030	0.030	
	LS3	0.019±0.0	0.019^{c}	0.019	0.019	H =19.9209
	LS4	0.013±0.0	0.015^{f}	0.015	0.015	*p* = 0.0029
	LS5	0.015±0.0	0.02^{e}	0.02	0.02	Df= 6
	LS6	0.017±0.0	0.017^{d}	0.017	0.017	
	LS7	0.004±0.0	0.004^{g}	0.004	0.005	
Wet	LS1	0.003±0.0	0.003^{e}	0.003	0.003	
	LS2	0.002±0.0	0.002^{g}	0.002	0.002	
	LS3	0.014±0.0	0.014^{f}	0.014	0.014	H =19.9209
	LS4	0.088±0.0	0.088^{b}	0.088	0.088	*p* = 0.0029
	LS5	0.038±0.0	0.038^{c}	0.037	0.038	Df = 6
	LS6	0.031±0.0	0.031^{d}	0.031	0.031	
	LS7	0.230±0.0	0.230^{a}	0.229	0.230	N = 3
	H =5.7092			*P*= 0.4565	Df= 6	

where SD = standard deviation, N = Sample size, values with different letters were significantly different

Season had no significant effect ($p > 0.05$) on the values of PO_4^{3-}in water (H (21) = 1.4639, $p = 0.4565$) in wet season. However, slightly higher values of PO_4^{3-} were noted during the wet season (*Median* = 0.03 ppm) as compared to during the dry season [(*Median* = 0.02 ppm) Figure 4.12] and can be related to surface runoff (Kimani *et al*., 2016**).**



4.5 Chemical parameters in sediments

Four metals and two anions were investigated in sediments just like in water. Mean and standard deviation values are given in the table 4.15.

Table 4.15: Levels (Mean± SD) of chemical parameters in sediments during the dry and wet season

Site		Parameters					
		pH (mg/Kg)	Cd (mg/Kg)	Fe (mg/Kg)	Mn (mg/Kg)	NO_3 (mg/Kg)	PO_4 (mg/Kg)
LS1	Dry	32.33 ±11.02	BDL	40274.92 ±1583.58	817.0 ±27.50	816.25 ±13.38	0.247 ±0.001
	Wet	26.14 ±10.26	3.16 ±0.88	1581.58 ±32.71	816.25 ±13.38	2.36 ±0.0	0.797 ±0.001
LS2	Dry	24.12 ±12.80	BDL	34204.17 ±2429.00	1156.67 ±22.13	408.00 ±7.87	0.816 ±0.001
	Wet	16.73 ±11.29	4.91 ±0.52	912.58 ±32.08	408.00 ±7.87	2.59 ±0.0	4.217 ±0.058
LS3	Dry	19.14 ±5.52	BDL	38433.33 ±1205.28	841.58 ±29.19	548.00 ±24.88	0.312 ±0.001
	Wet	14.97 ±6.59	BDL	1668.33 ±17.02	548.00 ±24.88	3.20 ±0.0	0.945 ±0.055
LS4	Dry	21.00 ±7.35	BDL	30413.33 ±4663.46	586.50 ±5.95	509.50 ±11.06	0.223 ±0.001
	Wet	14.93 ±6.06	BDL	2230.00 ±19.49	509.50 ±11.06	3.59 ±0.0	0.421 ±0.115
LS5	Dry	22.57 ±7.02	BDL	16279.17 ±687.42	249.92 ±15.25	425.58 ±6.11	0.519 ±0.001
	Wet	13.82 ±5.67	8.16 ±0.63	1796.67 ±74.25	425.58 ±6.11	4.01 ±0.0	0.965 ±0.000
LS6	Dry	26.73 ±6.12	BDL	33900.33 ±1645.60	734.17 ±5.92	515.83 ±5.89	0.525 ±0.001
	Wet	20.88 ±6.18	3.08 ±0.95	1447.17 ±19.42	515.83 ±5.89	3.83 ±0.0	0.843 ±0.002
LS7	Dry	25.06 ±6.29	BDL	46770.83 ±938.19	649.83 ±7.85	398.42 ±17.51	0.305 ±0.001
	Wet	21.58 ±1.71	BDL	1644.50 ±11.48	398.42 ±17.51	3.97 ±0.03	0.746 ±0.001

From the observed ranges, it is noted levels of lead, iron and manganese in sediments were lower in wet season than dry season. This observation is similar to that of a study on river Sio (Ondoo *et al.,* 2019). This can be attributed to washing away of the sediments from one location to another due to increased flow rate and turbulence of the water as it flows along the river (Ombaka *et al.*, 2012).

4.5.1 Lead

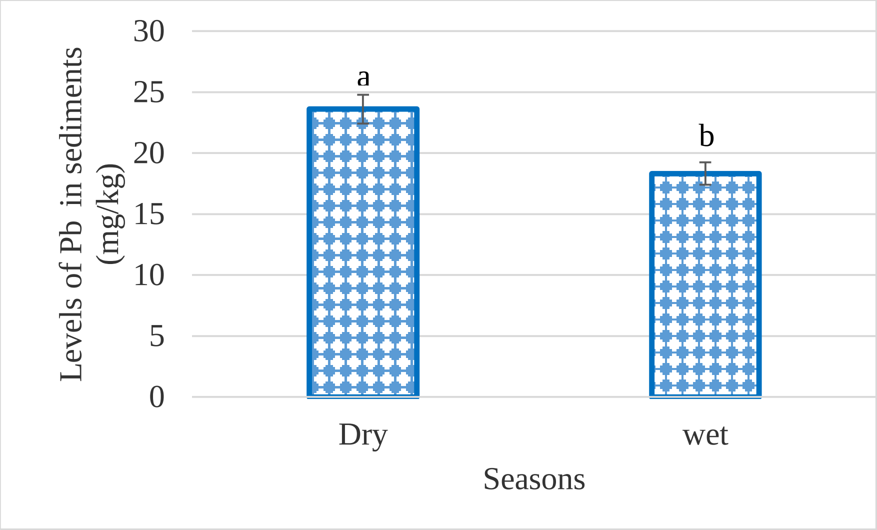
Mean range of lead were 19.14±5.52 to 32.33 ±11.02 to 44.90 in dry season and 13.82 ±5.67 to 26.14± 0.26mg/kg in the wet season. No significant differences were seen in levels of lead in all sites in the two seasons [(*H* (21) = 4.7273, *p*=0.579) (Table 4.16)].

Table 4.16: Analyzed levels of Pb in sediments along the river in dry and wet seasons

		Values of Pb (ppm)				
Seasons	Location	Means±SD	Median	Minimum	Maximum	Kruskal wallis
Dry	LS1	32.33±11.02	27.80	24.30	44.90	
	LS2	24.12±12.80	16.80	16.66	38.90	
	LS3	19.14±5.52	20.10	13.20	24.12	H =4.7273
	LS4	21.00±7.35	20.70	13.80	28.50	*p* = 0.5792
	LS5	22.57±7.02	19.50	17.60	30.60	Df= 6
	LS6	26.73±6.12	23.60	22.80	33.78	
	LS7	25.06±6.29	27.57	17.90	29.70	
Wet	LS1	26.14±10.26	22.34	18.32	37.75	
	LS2	16.73±11.29	10.77	9.67	29.75	
	LS3	14.97±6.59	17.80	7.44	19.67	H =6.6320
	LS4	14.93±6.06	13.11	9.99	21.70	*p* = 0.3562
	LS5	13.82±5.67	12.90	8.67	19.89	Df = 6
	LS6	20.88±6.18	17.77	16.87	27.99	
	LS7	21.58±1.71	20.68	20.50	23.55	N = 3
	H =9.3223			*p* = 0.1562	Df= 6	

where SD = standard deviation, N = Sample size

Season had significant ($p < 0.05$) effect on the Pb values in river sediment (H (1) = 5.2981, p = 0.0213) during wet season. Nonetheless, dry season had slightly higher values of Pb (*Median* = 23.6ppm) as compared to wet season [(*Median*= 18.32ppm) (Figure 4.13)]. This is attributed to dilution due to increased water volumes in wet (Ondoo *et al*., 2019).



Letters a and b show values differ significantly

Figure 4.13: Mean levels of lead n sediments in dry ad wet seasons

4.5.2 Cadmium

The level of cadmium was below detection limit in dry season. However, in the wet season the means ranged from 0.00 – 8.16 ±0.63mg/Kg.

Table 4.17: Analyzed levels of Cd in sediments along the river in wet season

Location	Mean	Median	Minimum	Maximum
LS1	3.17±0.88	3.25	2.25	4.00
LS2	4.92 ±0.52	4.75	4.50	5.50
LS3	0.00±0.00	0.00	0.00	0.00
LS4	0.00±0.00	0.00	0.00	0.00
LS5	8.17±0.63	8.25	7.50	8.75
LS6	3.08±0.95	3.50	2.00	3.75
LS7	0.00±0.00	0.00	0.00	0.00
	H (21)= 19.3991	p= 0.0035	df=6	

4.5.3 Iron

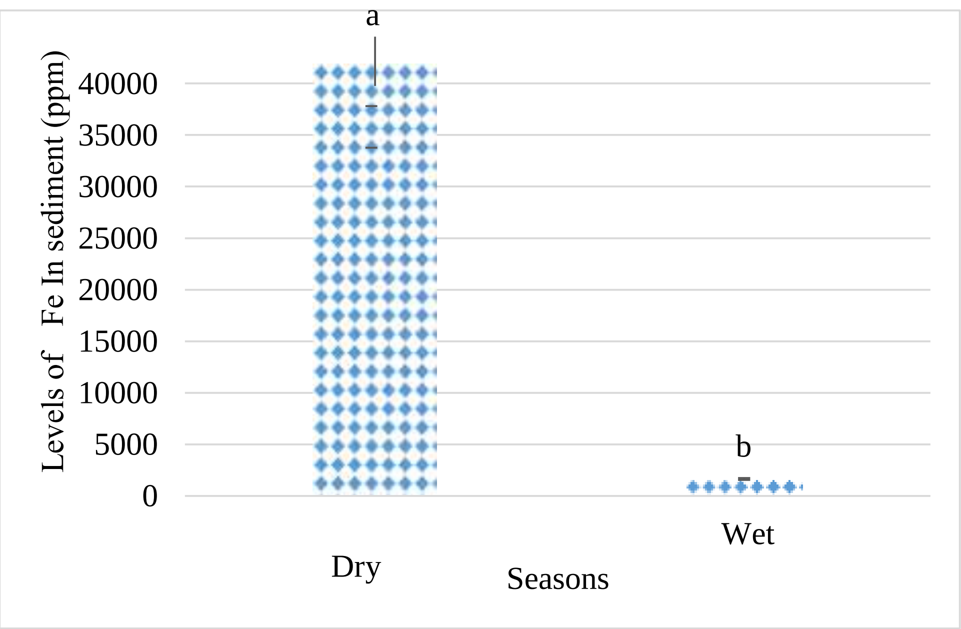
Of the four metals measured, mean levels of iron were highest both in dry and wet season. They were observed to range from16287.17± 687.42 to 46770.83± 938.19 mg/Kg and 912.58 ± 32.08 to 2230.00 ± 19.49 in dry and wet season respectively. The values for the Fe in sediment differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 18.303, $p = 0.0055$). Higher values of Fe were recorded at location LS7 with a *Median* of 46812.5ppm and was low in location at LS5 [(*Median* = 16537.5ppm) Table 4.18]. During the wet season a significant difference ($p < 0.05$) was noted in Fe values among the sample collection locations (H (21) = 19.4978, $p = 0.0034$) during wet season. Location LS4 had higher values of Fe (*Median*= 2241.0ppm). This may be due to the quarry site in the location which may introduce higher levels of iron that deposit on sediments (Sultan *et al*., 2011). Location LS2 had lower Fe (*Median*= 915.25ppm) values (Table 4.18).

Table 4.18: Analyzed levels of the Fe in sediments in sampling locations per Season

Location		Values of Fe (mg/ Kg) Means±SD	Median	Minimum	Maximum	Kruskal wallis
	LS1	40274.92±1583.58	41087.50^{b}	38450.00	41287.25	
	LS2	34204.17±2429.00	33000.00^{c}	32612.50	37000.00	
	LS3	38433.33±1205.28	37750.00^{b}	37725.00	39825.00	H =18.3030
Dry	LS4	30413.33±4663.46	32678.00^{c}	25050.00	33512.00	p = 0.0055
	LS5	16279.17±687.42	16537.50^{d}	15500.00	16800.00	df= 6
	LS6	33900.33±1645.60	32988.50^{c}	32912.50	35800.00	
	LS7	46770.83±938.19	46812.50^{a}	45812.50	47687.50	
	LS1	1581.58±32.71	1574.50^{d}	1553.00	1617.25	
	LS2	912.58±32.08	915.25^{f}	879.25	943.25	
	LS3	1668.33±17.02	1663.50^{c}	1654.25	1687.25	H =19.4978
Wet	LS4	2230.00±19.49	2241.00^{a}	2207.50	2241.50	p = 0.0034
	LS5	1796.67±74.25	1780.25^{b}	1732.00	1877.75	df = 6
	LS6	1447.17 had ±19.42	1457.75^{e}	1424.75	1459.00	N=3
	LS7	1644.50±11.48	1642.75^{c}	1634.00	1656.75	
		H =30.7674		p = < 0.0001		df= 1

where SD = standard deviation, N = Sample size, values followed by different letters are significantly different

Season significant ($p < 0.05$) effect on the Fe values in water (H (21) = 30.7674, $p <$ 0.0001) during wet season. The values of Fe was higher in the dry season (*Median* = 35800ppm) as compared to wet season [(*Median*= 1642.72ppm) Figure 4.14)] Lower values are attributed to dilution (Ondoo *et al*., 2019).



Letters a and b show values were significantly different

Figure 4.14: Mean levels of Fe in sediments in the dry and wet seasons

4.5.4. Manganese

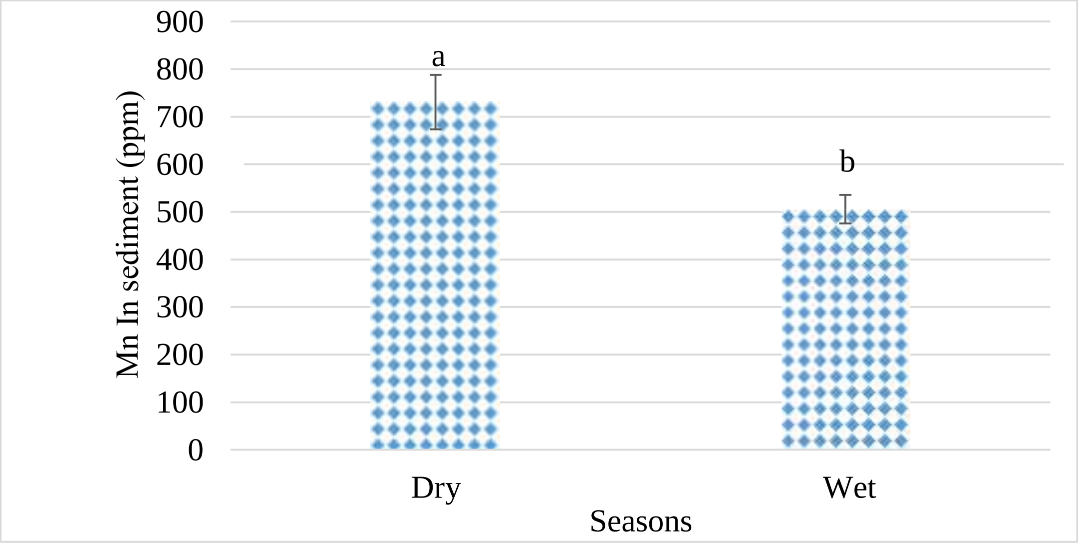
Manganese mean range was 249.92±15.25 to 1156.67±22.13mg/kg in dry season while in wet it was found to be 398.42±17.51. The values for the Mn in sediment differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 19.4065, p = 0.0035). Higher values of Mn were recorded at location LS2 with a *Median* of 1157.25 and lower in location at LS5 [(*Median* 242.0 ppm) Table 4.19]. During the wet season a significant ($p < 0.05$) difference was observed in Mn concentration in all the sampling locations (H (21) = 19.013, p = 0.0041). Location LS1 had higher values of Mn (*Median* = 816.0 ppm) while location LS7 had lower Mn (*Median* = 397.75 ppm) values (Table 4.19).

Table 4.19: Analyzed levels of the Mn in sediments in sampling locations per Season

		Values of Mn (mg/Kg)				Kruskal Wallis
Season	Location	Means±SD	*Median*	Minimum	Maximum	
Dry	LS1	817.0±27.50	810.25^{b}	793.50	847.25	
	LS2	1156.67±22.13	1157.25^{a}	1134.25	1178.50	
	LS3	841.58±29.19	849.50^{b}	809.25	866.00	*H* =19.4065
	LS4	586.50±5.95	584.25^{e}	582.00	593.25	*p* = 0.0035
	LS5	249.92±15.25	242.00f	240.25	267.50	df= 6
	LS6	734.17±5.92	730.75^{c}	730.75	741.00	
	LS7	649.83±7.85	652.50^{d}	641.00	656.00	
Wet	LS1	816.25±13.38	816.00^{a}	803.00	829.75	
	LS2	408.00±7.87	410.25d^{e}	399.25	414.50	
	LS3	548.00±24.88	547.25^{b}	523.50	573.25	*H* =19.0130
	LS4	509.50±11.06	505.50^{c}	501.00	522.00	*p* = 0.0041
	LS5	425.58±6.11	424.25^{d}	420.25	432.25	df = 6
	LS6	515.83±5.89	516.25^{c}	509.75	521.50	
	LS7	398.42±17.51	397.75^{e}	381.25	416.25	
		H =9.653			*p* = 0.0019	df= 1

where SD = standard deviation, N = Sample size =3

Season had significant ($p < 0.05$) effect on the Mn values in water (*H* (42) = 9.653, *p*= 0.0019) during wet season. The value of Mn was higher in the dry season (*Median* = 35800 ppm) as compared to wet season [(*Median* = 1642.72 ppm) Figure 4.15).



Letters a and b indicate values differ significantly

Figure 4.15: Mean levels of Mn in sediments in the dry and wet seasons

4.5.5 Nitrates

For the nitrate range in dry season was 1.95-9.72 mg/Kg and in wet season it was 2.27-4.99 mg/ Kg. The values for the NO_3^-in sediment differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 19.6747, p = 0.0032) (Ayenuddin *et al*., 2018). Higher values of NO_3^- were recorded at location LS2 with a *Median* of 9.72 ppm and was low in location at LS5 [(*Median* = 1.95 ppm) Table 4.20]. During the wet season a significant ($p < 0.05$) difference values of NO_3^- values in the sediment was recorded among the sampling location (H (21) = 19.6619, p = 0.0032) during wet season. Location LS7 had higher values of NO_3^- (*Median* = 4.98 ppm) while location LS6 had lower NO_3^- (*Median* = 2.27ppm) values (Table 4.20).

Table 4.20: Analyzed levels of the NO_3^-in sediments in sampling locations per Season

Location		Values of NO_3^-(ppm)				Kruskal Wallis
		Means±SD	Median	Minimum	Maximum	
Dry	LS1	5.08±0.002	5.08^{c}	5.08	5.0	
	LS2	9.72±0.002	9.72^{f}	9.72	9.72	
	LS3	5.05±0.004	5.05^{d}	5.05	5.05	H =19.6747
	LS4	2.57±0.002	2.57^{b}	2.57	2.58	*p* = 0.0032
	LS5	1.95±0.003	1.95^{e}	1.95	1.96	df= 6
	LS6	2.44±0.001	2.44^{a}	2.44	2.44	
	LS7	5.29±0.003	5.29^{g}	5.28	5.29	
Wet	LS1	3.06±0.01	3.06^{c}	3.06	3.07	
	LS2	3.44±0.00	3.44^{a}	3.44	3.45	
	LS3	2.71±0.01	2.71^{d}	2.70	2.72	H =19.6619
	LS4	4.16±0.01	4.16^{e}	4.15	4.17	*p* = 0.0032
	LS5	2.68±0.01	2.68^{g}	2.67	2.69	df = 6
	LS6	2.27±0.01	2.27^{f}	2.27	2.29	
	LS7	4.98±0.01	4.98^{b}	4.97	4.99	N = 3
	H =1.551			*P* =0.230	df= 1	

where SD= standard deviation, N = Sample size, values followed by similar small letters are not significantly different

Season had no significant ($p > 0.05$) effect on the NO_3^- values in sediment (*H* (42) = 1.551, $p = 0.2130$) during wet season. However, the values of NO_3^- were slightly higher in the dry season (*Median* = 5.05 ppm) as compared to wet season [(*Median* = 3.06 ppm) Figure 4.16)].

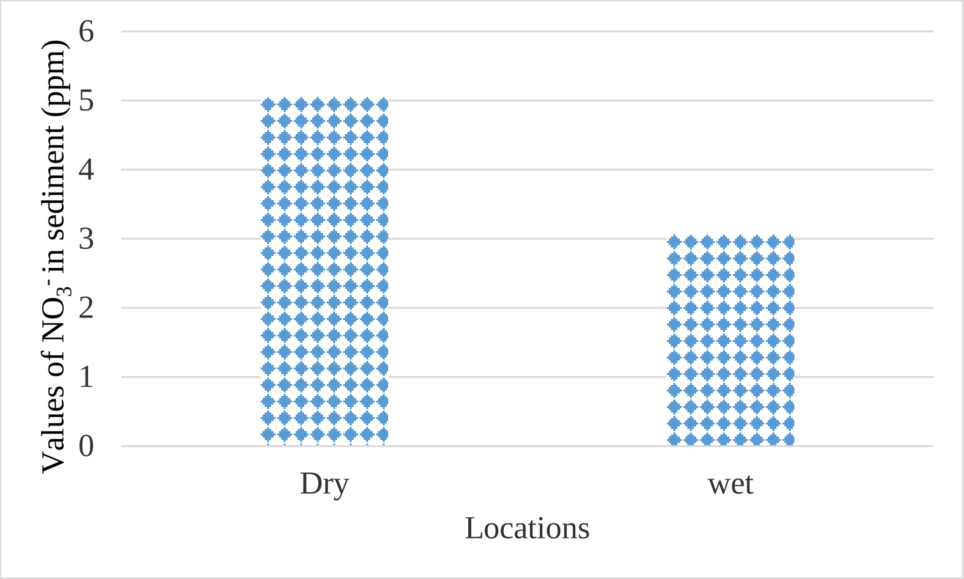


Figure 4.16: Levels of nitrates in sediments in the two seasons

4.5.6 Phosphates

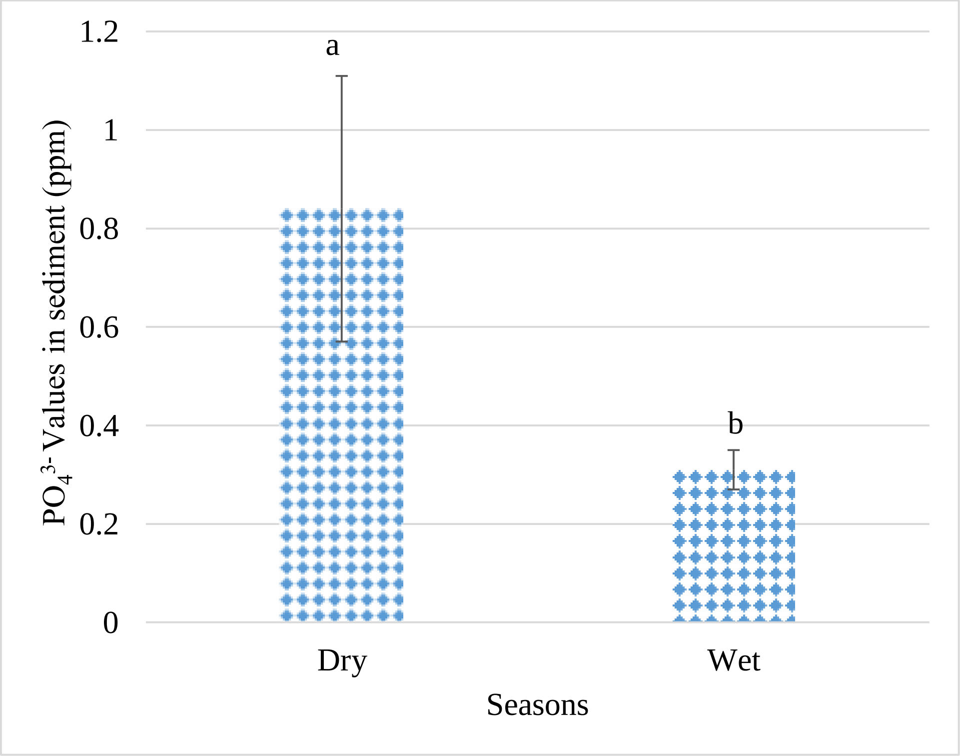
Phosphate mean levels ranged from 0.22±0.001to0.816±13.38 mg/kg in dry season and 0.421±0.115 to 4.217±0.058 in wet. It is observed that the levels of phosphates are lower in dry season than wet season and this agrees with results of Ondoo *et al*., 2019. The values for the PO_4^{3-}in sediment differed significantly ($p < 0.05$) among the sampling locations along River Mutonga during the dry season (H (21) = 19.413, p = 0.0035). Higher values of PO_4^{3-}were recorded at location LS2 with a *Median* of 0.816ppm and was low in location at LS4 [(*Median*= 0.223ppm) Table 4.21]. During the wet season a significant ($p < 0.05$) difference values of PO_4^{3-}values in sediment was observed among the sampling location (H (21) = 19.375, p = 0.0036). Location LS2 had higher values of PO_4^{3-}(*Median* = 4.15ppm) while location LS5 had lower PO_4^{3-} (*Median* = 0.355ppm) values (Table 4.21).

Table 4.21: Analyzed levels of PO_4^{3-} per season and sampling locations

Season	Location	N	Values of PO_4^{3-}(ppm)				Kruskal walis
			Means ±SD	Median	Minimum	Maximum	
Dry	LS1		0.247±0.001	0.247^{d}	0.246	0.247	
	LS2		0.816±0.001	0.816^{a}	0.815	0.816	
	LS3		0.312±0.001	0.312^{c}	0.311	0.312	H =19.413
	LS4		0.223±0.001	0.223^{e}	0.211	0.234	*p* = 0.0035
	LS5		0.519±0.001	0.519^{b}	0.510	0.528	Df= 6
	LS6		0.525±0.001	0.525^{b}	0.524	0.526	
	LS7		0.305±0.001	0.305^{c}	0.305	0.306	
Wet	LS1		0.797±0.001	0.797^{cd}	0.796	0.797	
	LS2		4.217±0.058	4.250^{a}	4.150	4.250	
	LS3		0.945±0.055	0.961^{b}	0.884	0.990	H =20.864
	LS4		0.421±0.115	0.355^{e}	0.354	0.554	*p* = 0.00001
	LS5		0.965±0.000	0.965^{b}	0.965	0.965	Df = 6
	LS6		0.843±0.002	0.843^{c}	0.841	0.845	
	LS7		0.746±0.001	0.746^{d}	0.745	0.746	N=3
			H =18.2355		*p*=0.0057	Df= 6	

Where SD= standard deviation, N = Sample size, Values with similar letters don't differ significantly

Season had significant ($p < 0.05$) effect on the values of PO_4^{3-}in water (*H* (42) = 20.8648, $p < 0.0001$) during wet season. Higher values of PO_4^{3-} was observed during the dry season (*Median* = 0.84 ppm) as compared to the values during the wet season [(*Median* = 0.31 ppm) (Figure 4.17)].



Letters a and b show values differ significantly

Figure 4.17: Mean levels of PO_4^{3-} in sediments in the dry and wet seasons

4.5.6 Correlation of Physical and chemical Property of Water in Dry and Wet Season

Table 4.22 below shows the correlation values between the physico-chemical parameters during the dry season. The table shows the association of any two parameters during the dry season. The values in brackets indicate p values.

Table 4.22: Correlation of physio-chemical parameters in water during dry season

	pH	Tem	Cond	Turb	TSS	TDS	**Pb**	Fe	**Mn**	NO_3^-	PO_4^{3-}
pH	1										
Temp	-0.525 (0.017)	1									
Cond	-0.169 (0.477)	0.008 (0.974)	1								
Turb	-0.404 (0.078)	0.831 (<.0001)	-0.179 (0.451)	1							
TSS	0.026 (0.913)	-0.218 (0.357)	0.276 (0.239)	-0.337 (0.146)	1						
TDS	0.271 (0.248)	-0.530 (0.016)	0.408 (0.074)	-0.540 (0.014)	-0.023 (0.923)	1					
Pb^{2+}	-0.239 (0.310)	0.584 (0.007)	-0.076 (0.751)	0.505 (0.023)	-0.306 (0.189)	-0.072 (0.763)	1				
Fe^{2+}	0.107 (0.653)	0.573 (0.008)	-0.248 (0.291)	0.579 (0.007)	-0.357 (0.123)	-0.468 (0.038)	0.279 (0.233)	1			
Mn^{2+}	-0.320 (0.169)	0.260 (0.268)	0.042 (0.862)	0.378 (0.100)	0.040 (0.868)	-0.080 (0.738)	0.355 (0.125)	-0.100 (0.676)	1		
NO_3^-	0.217 (0.358)	0.032 (0.893)	-0.058 (0.807)	0.264 (0.261)	-0.053 (0.825)	-0.011 (0.963)	0.570 (0.009)	0.045 (0.851)	0.299 (0.201)	1	
PO_4^{3-}	-0.175 (0.461)	-0.622 (0.003)	0.025 (0.916)	-0.393 (0.087)	0.248 (0.293)	0.317 (0.174)	-0.310 (0.183)	-0.744 (0.000)	0.381 (0.098)	0.047 (0.845)	1
Ms±SD	5.95±0.27	19.75±4.35	0.29±0.3	25.51±8.57	59.1±33.17	122.25±120	0.10±0.11	0.49±0.14	36.54±163.4	1.49±0.89	0.06±0.19
Min	5.67	13.4	0.1	13.26	4.0	28	0	0.23	0	0.49	0.004
Max	6.5	26.7	0.6	38.79	154.0	560	0.32	0.62	730.75	3.83	0.85

Where Temp = Temperature, Cond = Conductivity, Turb = Turbidity, TSS = Total suspended solids, TDS = Total dissolved solids, Ms = Means, SD = Standard deviation figure in brackets represent p values

There was a moderate negative significant (p <0.05) correlation (r = -0.525; p<0.017) between temperature and pH of water. This observation may be attributed to dissociation of water molecules to more H^+ ions and dissolution of acidic compounds into the water. High temperatures influence many chemical processes like dissolution of minerals which may increase water conductivity (Marina *et al*., 2013). There was a strong positive significant (p <0.05) correlation (r = 0.831; p <.0001) between water turbidity and water temperature. This is attributed to the fact that suspended matter in water absorbs heat radiation from the sun and releases the heat energy to water (Marina *et al*., 2013 and Islam *et al.,* 2014). Temperature had a moderate negative significant (p <0.05) correlation (r = -0.530; p = 0.016) with TDS in water (Table 4.21). Solubility of most compounds decreases with temperature (Marina *et al*., 2013).

There was a moderate positive significant (p <0.05) correlation between Pb (r =0.584; p = 0.007) and Fe (r = 0.573; p = 0.008) with temperature in water samples. The solubility of lead and iron compounds increases with increase in temperature thereby raising the levels of TDS. The PO_4^{3-} in water samples had a strong negative significant (p <0.05) correlation (r = -0.622; p = 0.003) with temperature. No significant (p >0.05) correlation was observed between water conductivity and other physico-chemical parameters. Water turbidity had a moderate negative significant (p <0.05) correlation with total dissolved solids. This is in agreement with the results found on Godavari water (Dasharath *et al*., 2018). The Pb had a moderate positive significant (p <0.05) correlation (r = 0.505; p = 0.023) with water turbidity. The Fe had a moderate positive significant (p <0.05) correlation (r = 0.505; p = 0.023) with water turbidity. This was in agreement with the findings of on research carried out on two rivers of Taihu Basin (Hong *et al*., 2019).

There was no significant ($p > 0.05$) correlation observed between total suspended solids and other physico-chemical properties of water (Puriatjarin *et al.*, 2021). A weak negative significant ($p < 0.05$) correlation (r = -0.468; $p = 0.038$) was observed between TDS and Fe (Muller, 2018). The Pb had a moderate positive significant ($p < 0.05$) correlation (r = 0.570; $p = 0.009$) with NO_3^-. Lastly, Pb had a strong negative significant ($p < 0.05$) correlation (r = 0.570; $p = 0.009$) with PO_4^{3-} (Table 4.21). Phosphates cause precipitation of lead. Correlation between $Cd^{2+}$and other physico-chemical parameters were not evaluated since it was below detection limit in most of the water samples collected. Table 4.23 represents correlation values for the physico-chemical parameters during the wet season. The table shows the association between any two physico-chemical parameters in the wet seasons.

Table 4.23: Correlation of physico-chemical parameters in water during wet season

	pH	Temp	Cond	Turb	TSS	TDS	Pb	Fe	Cd	Mn	NO_3^-	PO_4^{3-}
pH	1											
Temp	0.286 (0.208)	1										
Cond	0.454 (0.039)	0.249 (0.277)	1									
Turb	0.177 (0.443)	0.886 (<.0001)	0.163 (0.481)	1								
TSS	-0.140 (0.544)	0.330 (0.144)	0.240 (0.295)	0.375 (0.094)	1							
TDS	-0.355 (0.114)	-0.044 (0.850)	-0.824 (<.0001)	0.005 (0.984)	-0.105 (0.649)	1						
Pb^{2+}	0.091 (0.696)	0.848 (<.0001)	0.165 (0.476)	0.802 (<.0001)	0.416 (0.061)	-0.042 (0.856)	1					
Fe^{2+}	-0.460 (0.036)	-0.094 (0.686)	-0.151 (0.515)	0.148 (0.521)	0.295 (0.194)	0.161 (0.485)	-0.062 (0.791)	1				
Cd^{2+}	0.121 (0.603)	0.547 (0.010)	-0.241 (0.293)	0.739 (<.0001)	0.104 (0.654)	0.457 (0.037)	0.419 (0.059)	0.203 (0.378)	1			
Mn^{2+}	0.331 (0.143)	0.867 (<.0001)	0.371 (0.098)	0.860 (<.0001)	0.300 (0.186)	-0.283 (0.213)	0.799 (<.0001)	-0.010 (0.967)	0.442 (0.045)	1		
NO_3^-	-0.027 (0.907)	0.580 (0.006)	-0.111 (0.632)	0.735 (<.0001)	0.528 (0.014)	0.237 (0.300)	0.638 (0.002)	0.465 (0.034)	0.592 (0.005)	0.551 (0.010)	1	
PO_4^{3-}	0.170 (0.461)	0.840 (<.0001)	-0.003 (0.990)	0.918 (<.0001)	0.346 (0.124)	0.286 (0.209)	0.710 (<.0001)	0.166 (0.472)	0.867 (<.0001)	0.723 (0.000)	0.776 (<.0001)	1
Ms±SD	6.48±0.74	18.25±1.37	47.72±19.57	277±314.73	119.76±26.94	230±153.36	0.09±0.06	4.24±2.15	0.001±0.001	0.39±0.78	3.37±0.63	0.06±0.08
Min	5.54	16.20	35.6	60.0	79.0	16.0	0.03	2.06	0	0.01	2.36	0.002
Max	7.76	21.10	93.6	1002.0	180.0	776.0	0.24	7.74	0.002	2.28	4.01	0.230

Where Temp = Temperature, Cond = Conductivity, Turb = Turbidity, TSS = Total suspended solids, TDS = Total dissolved solids, Ms = Mean, SD = Standard deviation values

There was a moderate positive significant (p <0.05) correlation (r = 0.454; p <0.039) between conductivity and pH of water. A moderate negative significant (p <0.05) correlation (r = -0.460; p = 0.036) between Fe and water pH (Table 2). Temperature had a strong positive significant (p <0.05) correlation (r = 0.886; p <.0001) with water turbidity. There was a strong positive significant (p <0.05) correlation (r = 0.867; p <.0001) between water temperature and Mn. A strong positive significant (p <0.05) correlation (r = 0.840; p<.0001) was also observed between water temperature and PO_4^{3-}. The NO_3^- had a moderate strong positive significant (p <0.05) correlation (r = 0.580; p = 0.006) water temperature (Table 4.23). Water conductivity was observed to have a strong negative significant (p <0.05) correlation (r = -0.824; p <.0001) with TDS. This is in concordance with results of a study on correlation between conductivity and total dissolved solids (Ann, 2019).

A strong positive significant (p <0.05) correlation (r = 0.802; p <.0001) was observed between water turbidity and Pb. A strong positive significant (p <0.05) correlation (r = 0.802; p <.0001) was observed between water turbidity and Cd (r = 0.739; p <.0001). A strong positive significant (p <0.05) correlation (r = 0.860; p <.0001) was observed between water turbidity and Mn. A strong positive significant (p <0.05) correlation (r = 0.918; p <.0001) was observed between water turbidity and PO_4^{3-}. The positive correlation between ions and turbidity can be due to the fact that presence of dissolved ions adds to increased water turbidity (Dasharat *et al*., 2018) (Table 4.23)

4.5.7: Correlation of physico-chemical parameter of water and sediment in wet season

Table 4.24 below shows correlation between physico-chemical parameters of water and sediments in the wet season. The correction for dry season was not considered since some of the parameters were below detection limit during the dry season.

Table 4.24: Correlation of physico-chemical parameters in water and sediments in the wet season

Levels in water	Levels of chemicals in the river sediment (ppm)					
	Pb	Fe	Cd	Mn	NO_3^-	PO_4^{3-}
Pb	-0.026 (0.874)	-0.026 (0.871)	-2.211 (0.185)	-0.161 (0.369)	-0.199 (0.213)	-0.221 (0.164)
Fe	-0.381 (0.014)	-0.777 (<0.0001)	0.687 (<0.0001)	-0.511 (0.001)	-0.369 (0.017)	-0.630 (<.0001)
Cd	-0.246 (0.121)	-0.212 (0.184)	0.076 (0.638)	-0.412 (0.007)	0.109 (0.499)	-0.557 (0.001)
Mn	-0.189 (0.236)	-0.710 (<.0001)	0.343 (0.028)	-0.563 (0.001)	-0.235 (0.139)	-0.558 (0.001)
NO_3^-	-0.249 (0.116)	-0.614 (<.0001)	0.461 (0.002)	-0.470 (0.002)	-0.381 (0.014)	-0.566 (0.001)
PO_4^{3-}	-0.020 (0.900)	-0.668 (0.777) 17289⊥17437	-0.160 (0.319)	-0.215 (0.176)	0.054 (0.739)	-0.091 (0.571)

Mean± SD 21.27±8.38 1.41±2.52 599.81±251.84 3.87±2.08 2.02±7.58
Min (ppm) 7.44 879.24 0 3.83 0.02 0.21 Max (ppm) 44.90
47688.00 8.75 1179 9.72 49.0 where SD = Standard deviation

Values in brackets show correction coefficients, p-values

Lead in sediment formed weak non significance (p >0.05) correlation with all other chemicals assessed in water samples along River Mutonga. There was a strong negative significant (p <0.05) correlation (r = -0.777; p <0.0001) between Fe in sediment and Fe in water samples. This could be assigned to the release of metal from the sediments into the water (Ademuyiwa *et al*., 2018). There was a strong negative significant (p <0.05) correlation (r = -0.710; p <0.0001) between Fe in sediment and Mn in water samples. The findings are in concordance with results of a study on relationship between heavy metals in water and sediments (Selda *et al*., 2012). There was a strong positive significant (p <0.05) correlation (r = 0.687; p <.0001) between Cd in sediment and Cd in water (Table 21). A weak positive significant (p<0.05) correlation (r = 0.343; p = 0.028) was observed between Cd in sediment and Mn^{2+} in water samples. A moderate positive significant (p <0.05) correlation (r = 0.461; p = 0.002) was observed between Cd in sediment and NO_3^-in water samples (Table 24). This could also be attributed to common source of the parameters (Ademuyiwa *et al*., 2018). There was a moderate significant (p <0.05) correlation (r = -0.511; p = 0.0001) between Mn in sediment and Fe in water samples. A moderate negative significant (p <0.05) correlation (r = -0.563; p = 0.001) was observed between Mn in sediment and Mn in water samples. This is a similar observation to that of iron implying manganese is also released from sediments to the water during the wet season (Ademuyiwa *et al*., 2018).

A moderate negative significant (p <0.05) correlation (r =-0.470; p = 0.002) was observed between Mn in sediment and NO_3^-in water samples (table 21). Other studies have showed that sediments containing iron and manganese in +2 oxidation state have low levels or no nitrates. This is attributed to the ability of the two metallic ions to promote the process of dinitrification (Marina *et al*., 2012). A weak negative significant (p <0.05) correlation (r = -0.369; p = 0.017) was observed between NO_3^- in sediment and Fe in water samples. A weak negative significant (p <0.05) correlation (r = -0.381; p = 0.014) was observed between NO_3^- in sediment and NO_3^- in water samples (table 4.24). This also agrees with the results on study on correlation between nitrates and iron in water (Marina *et al*., 2012). A weak strong negative significant (p <0.05) correlation (r = -0.630; p <.0001) was observed between PO_4^{3-} in sediment and Fe in water samples.

A moderate negative significant (p <0.05) correlation (r = -0.557; p = 0.001) was observed between PO_4^{3-} in sediment and Cd in water samples. A moderate negative significant (p <0.05) correlation (r = -0.566; p = 0.001) was observed between PO_4^{3-} in sediment and NO_3in water samples (Table 4.24). This did not agree with results of a study on Isiukhu River (Oremo *et al*., 2020).

4.6 Biological parameters

4.6.1 Levels of Coliform

The mean values of total and fecal coliform for the dry and wet seasons are presented in Table 4.25.

Fecal coliform is a subset of total coliform. The measured level of total coliform was between 41.53 and 150.53cfu/100 ml of samples in dry season and between 89.29 and 467.33 cfu/100 ml in rainy season. The fecal coliform levels ranged between 7.86 and 54.54 cfu/100ml in the dry period and between 24.23 and 104.39cfu/100 ml in the wet season. The observed levels agree with those of other researchers (Ombaka et al., 2013; Kithaka et al., 2020). It was noted that measured levels of the two parameters were higher in the wet season than dry season. These can be attributed to improper disposal of household garbage and human waste from homesteads located near the river through surface run-off (Ombaka et al., 2013, and Ayennudin et al., 2018). The observed levels are higher than WHO (2011) set limits implying the water is unsuitable for use.

Table 4.25: Mean (SD) of total and fecal coliform in the dry and wet season

	Total Coliform (cfu)			Faecal Coliform (cfu)
Location	Dry season	Wet season	Dry season	Wet season
LS7	150.19^{a}	467.33^{a}	54.54^{a}	150.19^{a}
LS4	89.14^{ab}	89.29^{d}	19.70^{b}	37.63^{de}
LS3	89.79^{ab}	98.51^{cd}	18.36^{b}	52.6_{cd}
LS5	68.57^{bd}	201.88^{b}	13.78^{bc}	79.05^{bc}
LS2	68.57^{bd}	128.29^{bcd}	12.08^{bc}	24.23^{e}
LS1	52.7^{bd}	176.99^{bc}	9.59^{c}	65.65^{bcd}
LS6	41.53^{cd}	222.99^{b}	7.86^{c}	104.39^{ab}
Mean	74.19	170.57	54.54^{a}	62.92
CV	8.869	7.117	19.70^{b}	8.284
LSD	1.95	1.9	18.36^{b}	1.82

Where CV = Coefficient of variation, CFU = Colony forming units, LSD = Least significant difference.
Values followed by same letters in the same column are not significantly different at α = 0.05.
Values followed by similar letters are not significantly different

During the dry season, values for the total coliform differed significantly ($p < 0.05$; Table 4.24) among the location sampled and was significantly higher (150.19 cfu/100ml) in location LS7 and was significantly lower (41.53cfu/100ml) in location LS6. The higher levels in LS7 can be attributed to direct watering of animals in the river where the animals deposit their fecal waste into the river. Values for the fecal coliform differed significantly ($p < 0.05$) among the locations sampled with location LS7 recording significantly higher values (467.33 cfu /100ml) and location LS4 recording significantly lower values [(89.29 cfu/100ml)] during the same season. The high levels of fecal and total coliform can be attributed to the fact that FC is a subset of TC (Kithaka *et al.*, 2020). As the river proceeds downstream, bacterial load increases (Kshama *et al.*, 2011).

During the wet season, values for the total coliform differed significantly ($p < 0.05$) among the location sampled and was significantly higher (54.54 cfu/100ml) in location LS7, and significantly lower (7.86 cfu/100ml) in location LS6. Values for the fecal coliform differed significantly ($p < 0.05$) among the locations sampled with location LS7 recording significantly higher values (150.19 cfu/100ml) and was significantly lower in location LS2 [(24.23cfu/100ml) Table 23]. This observation on location 7 is similar to dry season and can be explained by the same fact (Kithaka *et al*., 2020 and Kshama *et al*., 2012) (Table 4.25). Values for the total coliform differed significantly (p <.05; table 4.24) by seasons with wet season recording higher values (170.58 cfu/100ml) (Ayennudin *et al*., 2018 and Mahmood *et al*., 2014) while dry season recorded lower values (74.19 cfu/100ml). Values for the fecal coliform differed significantly ($p < 0.05$) by seasons with wet season recording significantly higher values (62.92 cfu/100ml) while dry season recorded significantly lower values [(15.82cfu/100ml) Figure 4.19] (Ayennudin *et al*., 2012).

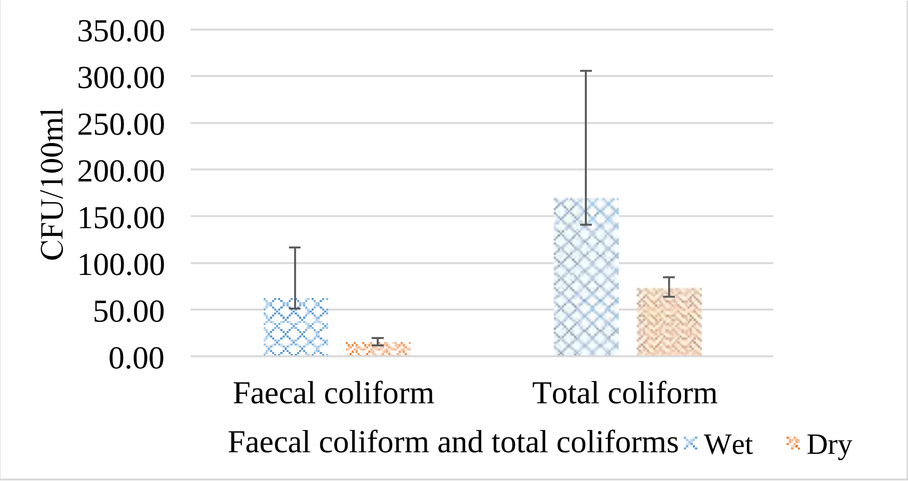


Figure 4.18: Mean levels of fecal and total coliform in water in the dry and wet seasons

4.6.2 Correlation of Physico-chemical parameters and Coliform bacteria

In the dry season, there was a moderate negative significant (p <0.05) correlation between the values for the total coliform bacteria and level of nitrates along River Mutonga (r = -0.501; p = 0.021). Moderate negative significant (r = -0.451; p = 0.040) correlation was observed between total coliform bacteria and level of phosphorus in water (Table 4.26). In the dry season, there was moderate negative significant (p <0.05) correlation was observed on the values for the fecal coliform bacteria and values of nitrates along River Mutonga (r = -0.456; p = 0.038). Similarly, a moderate negative significant (r = -0.563; p = 0.008) correlation was observed between the values of fecal coliform bacteria and level of phosphorus (Table 4.26). This is in line with results of Kolarevic *et al*, (2012). In the wet season, a strong positive significant (p <0.05) correlation was observed between the values for the total coliform bacteria and water pH (r = 0.629; p = 0.002). Moderate positive significant (p <0.05) correlation was observed between the values for the total coliform bacteria and water conductivity (r = 0.536; p = 0.012). Moderate positive significant (p <0.05) correlation was observed between the values for the total coliform bacteria and total dissolved solids [(r = 0.477; p = 0.0129) Table 4.26].

In the wet season, a moderate positive significant (p <0.05) correlation was observed between the values for the fecal coliform bacteria and water temperature (r = 0.575; p = 0.006). Water conductivity had a moderate positive significant (p <0.05) correlation with values for the fecal coliform bacteria [(r = 0.536; p = 0.016) Table 4.26] (Hanna *et al*., 2022). Moderate positive significant (p <0.05) correlation was observed between the values for the fecal coliform bacteria and total dissolved solids (r = 0.555; p = 0.009). The values for the fecal coliform bacteria had a moderate positive significant (p

<0.05) correlation with the values for Pb (r = -0.495; *p* = 0.023). The values for the fecal coliform bacteria had a moderate positive significant (*p* <0.05) correlation with the values for NO_3^-(r = 0.552; *p* = 0.01). Similarly, values for the PO_4^{3-} in water had moderate positive significant (*p* <0.05) correlation with the values for the fecal coliform bacteria [(r = 0.552; *p* = 0.01) Table 4.26]. This agrees with the results observed by Ayenuddin *et al.*, (2012) and was attributed to surface runoff which carries contaminated water into the river.

Table 4.26: Correlation between Coliform and physico-chemical properties of water during wet and dry season

Parameter	Dry season		Wet season	
	Total Coliform	Faecal Coliform	Total Coliform	Faecal Coliform
Ph	0.151 (0.515)	0.122 (0.598)	0.629 (0.002)	0.369 (0.100)
Temp	0.237 (0.301)	0.346 (0.125)	0.321 (0.157)	0.575 (0.006)
Cond	-0.062 (0.791)	0.123 (0.594)	0.536 (0.012)	0.518 (0.016)
Turb	0.033 (0.888)	0.012 (0.960)	0.304 (0.180)	0.482 (0.027)
TSS	-0.106 (0.648)	-0.073 (0.753)	0.477 (0.029)	0.555 (0.009)
TDS	0.159 (0.490)	0.141 (0.542)	-0.327 (0.148)	-0.193 (0.402)
Pb^{2+}	0.002 (0.993)	0.072 (0.755)	0.243 (0.288)	0.495 (0.023)
Fe^{2+}	0.380 (0.089)	0.387 (0.083)	-0.033 (0.888)	0.004 (0.987)
NO_{3-}	-0.501 (0.021)	-0.456 (0.038)	0.410 (0.065)	0.552 (0.010)
PO_{43-}	-0.451 (0.040)	-0.563 (0.008)	0.317 (0.161)	0.529 (0.014)
Mean ± SD	85.00±53.69	20.29±17.78	204.90±135.12	75.81± 47.19
Min	34.00	6.00	58.00	17.00
Max	280.00	82.00	540.00	220.00

Where Temp= Temperature, Turb= Turbidity, TSS= Total dissolved solids, Cond= Conductivity, Values in parenthesis are p values (α=0.05), calculated from SD

CHAPTER FIVE: CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The aim of this research was to determine the levels of physical, chemical, and biological properties of water and sediments along River Mutonga in dry and wet seasons. From the results the following was concluded;

i. It was discovered that significant differences exist in levels of all the physical parameters between seasons. Significant differences do not exist in levels of TSS between the sample collection sites in the two seasons.
ii. Levels of all the chemical parameters in water differ significantly among the sampling locations. Cadmium and manganese levels are below detection limits in all sites during dry season. Values of all parameters differ significantly between the two seasons except those of phosphates.
iii. In sediments, the levels of all the heavy metals and anions vary significantly among the sampling sites in both seasons apart from those of lead. They are also found to vary significantly between seasons except those of nitrates. It is also observed that the values of all the parameters are significantly higher in dry season.
iv. The levels of total and fecal coliform vary significantly among the sampling locations in both seasons. They are also found to differ significantly between seasons with the wet season recording significantly higher levels than dry season.
v. From the results it is noted that the levels of turbidity, TSS, Iron, Lead and coliform bacteria are above the WHO maximum permissible levels suggesting that the water is polluted due to high levels of the mentioned parameters.

5.2 Recommendations

5.2.1 Actionable areas

A regular check on amount of water quality parameters should be done to ensure it is safe for use. Proper disposal of domestic waste and sanitation should be encouraged by the two County governments.

5.2.2 Further studies

It is recommended that more research should be done to determine the levels of other heavy metals, pest side residues and polycyclic aromatic hydrocarbons (PAH s) in soil samples in farmlands along the river.

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APPENDICES

Appendix I: Research License from NACOSTI

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Appendix II: MPN table used for the total and feacal coliform evaluation

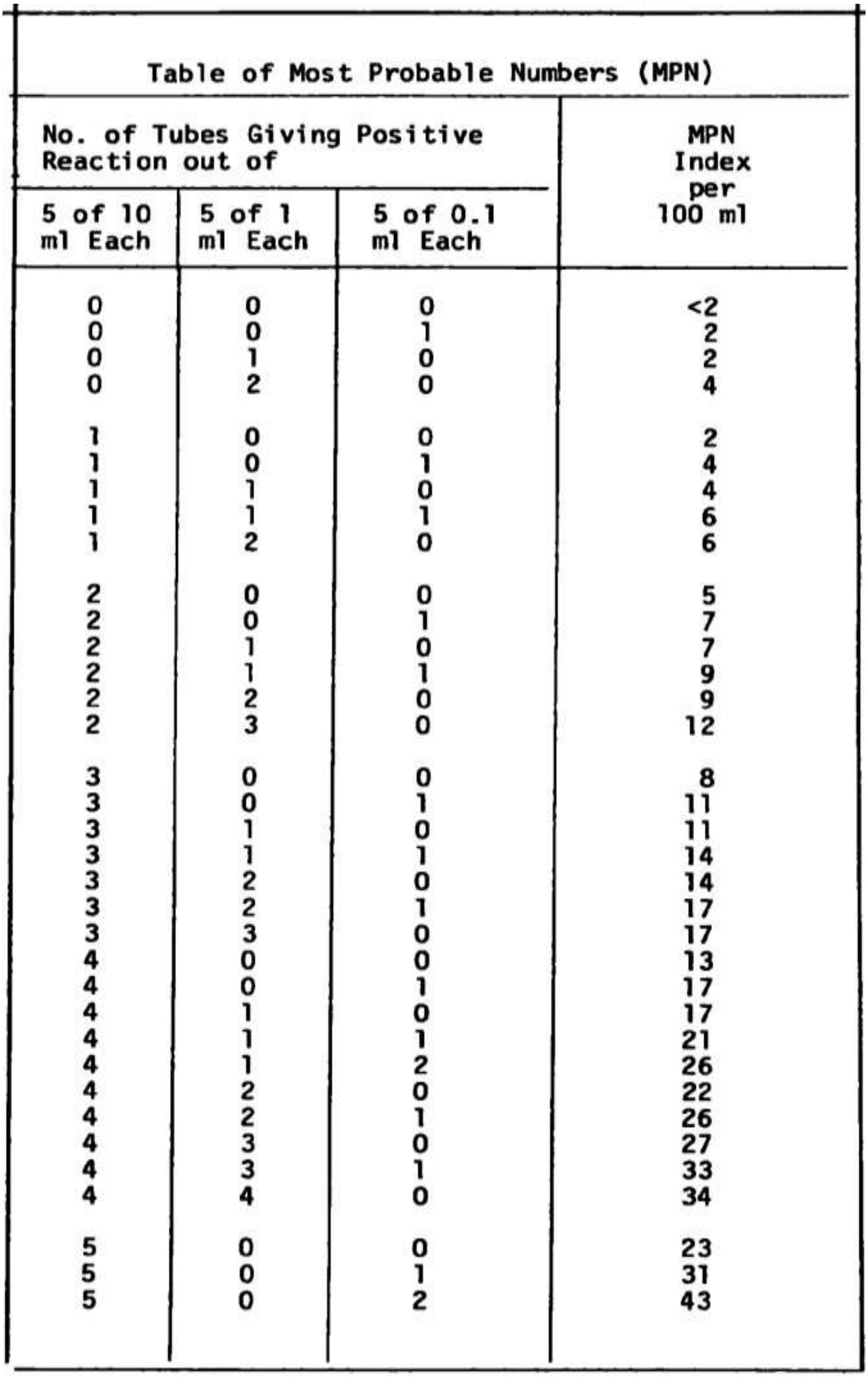

Table of Most Probable Numbers (MPN)

No. of Tubes Giving Positive Reaction out of			MPN Index per 100 ml
5 of 10 ml Each	5 of 1 ml Each	5 of 0.1 ml Each	
0	0	0	<2
0	0	1	2
0	1	0	2
0	2	0	4
1	0	0	2
1	0	1	4
1	1	0	4
1	1	1	6
1	2	0	6
2	0	0	5
2	0	1	7
2	1	0	7
2	1	1	9
2	2	0	9
2	3	0	12
3	0	0	8
3	0	1	11
3	1	0	11
3	1	1	14
3	2	0	14
3	2	1	17
3	3	0	17
4	0	0	13
4	0	1	17
4	1	0	17
4	1	1	21
4	1	2	26
4	2	0	22
4	2	1	26
4	3	0	27
4	3	1	33
4	4	0	34
5	0	0	23
5	0	1	31
5	0	2	43

Table of Most Probable Numbers (MPN)

No. of Tubes Giving Positive Reaction out of			MPN Index per 100 ml
5 of 10 ml Each	5 of 1 ml Each	5 of 0.1 ml Each	
5	1	0	33
5	1	1	46
5	1	2	63
5	2	0	49
5	2	1	70
5	2	2	94
5	3	0	79
5	3	1	110
5	3	2	140
5	3	3	180
5	4	0	130
5	4	1	170
5	4	2	220
5	4	3	280
5	4	4	350
5	5	0	240
5	5	1	350
5	5	2	540
5	5	3	920
5	5	4	1600
5	5	5	≥2400

Appendices III: Anova tables for the total coliform for dry and wet seasons

Total coliform dry season

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	6	0.58479789	0.09746632	3.54	0.0240
Error	14	0.38520430	0.02751459		
Corrected Total	20	0.97000219			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
Location	6	0.58479789	0.09746632	3.54	0.0240

Total coliform wet season

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	6	1.08578325	0.18096387	7.17	0.0012
Error	14	0.35320490	0.02522892		
Corrected Total	20	1.43898815			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
Location	6	1.08578325	0.18096387	7.17	0.0012

Appendices IV: Anova tables for the faecal coliform for dry and wet seasons

feacal coliform dry season

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	6	1.37662846	0.22943808	8.88	0.0004
Error	14	0.36180720	0.02584337		
Corrected Total	20	1.73843566			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
Location	6	1.37662846	0.22943808	8.88	0.0004

faecal wet season

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	6	1.28662945	0.21443824	9.66	0.0003
Error	14	0.31082569	0.02220184		
Corrected Total	20	1.59745514			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
Location	6	1.28662945	0.21443824	9.66	0.0003

Appendices V: Anova tables for the effect of seasons on faecal coliform and total coliforms

Total coliform dry season

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	1	1.37267020	1.37267020	22.79	<.0001
Error	40	2.40899034	0.06022476		
Corrected Total	41	3.78166054			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
SEASON	1	1.37267020	1.37267020	22.79	<.0001

Faecal coliform

Source of variation	df	Sum of Squares	Mean Square	F Value	*p*-value
Model	1	3.77553804	3.77553804	45.27	<.0001
Error	40	3.33589080	0.08339727		
Corrected Total	41	7.11142885			

Source of variation	df	Type III SS	Mean Square	F Value	*p*-value
SEASON	1	3.77553804	3.77553804	45.27	<.0001